Thinking with your Hands
Tacit Problem Reframing
with Interaction Design Students

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Abstract

This thesis explores pedagogic practice in Interaction Design through the development and evaluation of a pedagogic methodology for Interaction Design students, specifically the teaching of problem reframing in design. It describes the process of designing an environment that simulated the experience of problem reframing through 'design thinking', and the findings from that exploration.

Peter Rowe described 'design thinking' as a way of seeing and understanding the world *while* bringing about change, to describe the creative process at work in design (1987). For designers, the specific ability to solve design problems is important. When design problems involve 'problem reframing', then the ability to reframe that situation is an essential element of design ability, of design thinking (Dorst 2015). With the application of what design studies call the 'divergent' and 'convergent' thinking processes, this resolving of design problems can be accomplished (Guilford 1967; Lawson 2006).

This thesis explores from a Constructivist/Constructionist perspective, where understanding is not transmitted to the individual, but is constructed by the individual (Piaget 2013), and where this mental construction of knowledge is accelerated by building physical objects (Papert and Harel 1991). This research also explores experiential learning and the issues that surround 'tacit knowledge', knowledge that is difficult to transfer by words or writing and can only be acquired through practical experience in context (Polanyi 1966).

For a design student to experience solving design puzzles in a simulated environment, the solution-space of 'insight puzzles' was chosen. Insight puzzles have equivalence with design problems, as both need problem reframing to resolve them (Weisberg 2015).

The design of the pedagogic exploration was informed by a theoretical framework, based on Self-determined Learning, a macro-theory of human motivation that focuses on self-determined behaviour and the social conditions that promote it, and general Pedagogic Engagement theory.

The ultimate objective of Interaction Design pedagogy is to prepare design students for their professional 'design practice'. Therefore, this thesis is a 'design study' (Fallman 2008), aiming to describe and understand rather than create and change, with the overall goal to contribute to an accumulated body of knowledge within the discipline of Interaction Design pedagogy.

Declaration

This thesis is presented as fulfilment of the requirements for the degree of Doctor of Philosophy, at the University of Limerick, Dept. of Computer Science and Information Systems, Faculty of Science and Engineering. It is entirely my own work and has not been submitted to any other University or higher education institution, or for any other academic award in this University. Where use has been made of the work of other people, it has been fully acknowledged and referenced.

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1 Introduction

1.1 Problem Statement

This thesis explores pedagogic practice in Interaction Design through the development and evaluation of a pedagogic methodology for Interaction Design students, specifically the teaching of problem reframing in design. The design process of creating an environment that simulated the experience of problem reframing through 'design thinking' is discussed, and the findings from that exploration are discussed.

To become a designer, a design student must learn to think like a designer. To describe this thinking process, Donald Schön, in *The Reflective Practitioner* (1983), used the term 'reflection-in-action'. Bryan Lawson, in *How Designers Think* (1990), and Peter Rowe, in *Design Thinking* (1987), used the term 'design thinking'. They all referred to a way of seeing and understanding the world *while* bringing about change, and the term 'design thinking' (Brown 2008) is an attempt to describe the creative process at work in design (Vial 2013). But, while all designers are connected by actions that aim to change existing situations into preferred ones (Simon 1969), designers do not think homogenously. Fashion Designers and Interaction Designers must both be creative and solve problems, but not in the same way and not with the same problems.

For designers, the ability to solve design problems is obviously important. When design problems involve 'problem reframing' then, according to Schön (1983), the ability to reframe the situation is an essential element of design ability, of design thinking. This resolving of design problems is accomplished through the application of both divergent and convergent thinking processes (Lawson 1990; Rowe 1987). The term 'divergent thinking' describes the generation of multiple alternative problem solutions (Vincent et al. 2002). The term 'convergent thinking' describes the generation of the single correct answer to a defined question (Simonton 2014).

When an Interaction Design student does not yet have the experience and knowledge to visualize and resolve a design problem, a pedagogic bridge can be constructed to overcome this ideation gap (Dorta *et al.* 2008). Design knowledge can be mediated by words, as in the traditional lecture format. But design ideas can also be expressed "through the medium of doing and making", through material forms (Archer 1979,

p.19), as they are in the Design Studio pedagogical environment, where students learn in the context of design projects (Jonassen and Hung 2008).

This research focusses on pedagogic practices with Interaction Design students and the construction of such a pedagogic bridge, by exploring the issues that surround tacit knowledge, knowledge that is difficult to transfer by words or writing and can only be acquired through practical experience in context (Polanyi 1966; Rebert 1989).

1.2 Research Questions

According to Papert, Constructionist Theory can assist students with the development of their design thinking (1991). Constructionism is directly inspired by Constructivism, a theory from the field of cognitive science. When applied to pedagogy, Constructivism is a theory of learning where understanding is not brought about through the transmission of information but is constructed *with* the information (Kanselaar 2002), where no understanding is ever built on a tabula rasa but all learning involves making continuous "comparisons and judgements of similarity and difference" (Von Glasersfeld 1989, p.128). Advocates of Constructionism, a theory directly inspired by Constructivism, claim this mental construction of knowledge is accelerated when students build physical objects (Papert and Harel 1991).

Based on the work of Weisberg, a solution-space worth exploring is the application of Insight Puzzles, as they have equivalence with design problems. This is because of their similar conceptual structure and skills required to solve them (Weisberg 2015), with problem reframing being a necessary step in solving both insight puzzles and design problems.

According to researchers in pedagogic engagement, there are direct links between motivation, engagement, and creativity (Fredricks *et al.* 2004; Wang *et al.* 2016). Motivation is the direction and intensity of one's activities (Maehr and Meyer 1997), answering the question of "why am I doing this?" (Appleton *et al.* 2008, p.11). Engagement refers to a student's active involvement and participation in school-based activities and has been studied actively for decades (Reeve et al. 2004; Appleton et al. 2008; Fredricks and McColskey 2012).

To explore from these perspectives, a pedagogic environment was created where design students could build and rebuild physical objects that were also insight puzzles. Insight

puzzles, by definition, require reframing to solve them. Through their interactions with these puzzles, tacit design knowledge of reframing could be individually constructed.

The research questions for this thesis are:

Q1. Under what conditions can an Interaction Design student tacitly develop their comprehension of the abstract design concept of problem reframing?

Q2. What is it about attempting to solve physical insight puzzles that affects the engagement of an Interaction Design student in their design studies?

This research was motivated by a desire to contribute to pedagogic practice in Interaction Design. A literature review based of the history of design pedagogy is made, to understand why design pedagogic practice is the way it is and to discern what improvements could be made. After establishing a conceptual framework based on this review of historical and contemporary psychological theories of learning and pedagogical theories of teaching, the researcher employed a Constructionist approach to create 3 physical insight puzzles, each representing 3 Industrial Design examples of 'design thinking'. Participants (all were design students: 28 were Interaction Design; 3 were Industrial Design) were invited to attempt to solve these puzzles. To solve any of these puzzles, the design students would need to reframe the original argument and then rebuild the puzzle, to create a design solution that would satisfy the original design brief.

Instead of passively listening to a lecture or reading a book explaining an abstract concept such as problem reframing, mediated through language and examples, students would (re)enact those examples themselves, coming to an understanding of that same concept through tacit learning. The tangible nature of the puzzles meant that students would be 'thinking with their hands', reasoning in a way different from just using their mind.

The design and format of the pedagogic exploration was informed by a theoretical framework, based on Self-determined Learning, (a macro-theory of human motivation that focuses on self-determined behaviour and the social conditions that promote it), and general Pedagogic Engagement theory (Deci *et al.* 1991).

The research in this thesis describes the design and implementation of a pedagogic exploration and discusses the results from it to contribute to the growing knowledge base of pedagogic practice in Interaction Design. The ultimate objective of Interaction Design pedagogy is to prepare design students for their professional design practice. This thesis is a design study (Fallman 2008). The aim is to understand rather than change and has the goal of contributing to the body of knowledge within the discipline of Interaction Design pedagogy.

1.3 Thesis Outline

Following this introduction, Chapter 2 is divided into three sections. First, there is a critical review of the relevant literature regarding psychological theories of learning and pedagogical theories of teaching, and the issues that surround design pedagogy. Then, this thesis' Conceptual Framework, based on the literature review, is discussed. Lastly, the Theoretical Framework that influenced the design of the exploration, based on Self-determined Learning theory, is discussed.

Chapter 3 presents the context and methodological approach for this research. In this chapter, the format and setting of the exploration is described. The data gathering methods of a 4-camera video recording of all puzzle-solving activities, an individual Likert-style survey (the Academic Motivation Scale), and the follow-up semi-structured interviews with all participants are also discussed.

Chapter 4 presents the results from the exploration. The analysis of the data takes the form of a quantitative analysis of the video recordings, a quantitative analysis of their completed Academic Motivation Scale survey, and a qualitative thematic analysis of their interviews.

Chapter 5 discusses the meaning of those results, and the contribution to the practice of Interaction Design pedagogy.

Chapter 6 summarizes the research findings.

Chapter 7 discusses future research.

Finally, the Appendices present the raw data from all the explorational findings.

2 A Conceptual & Theoretical Framework

2.1 Introduction

This chapter presents the literature review, the resulting conceptual framework, and the theoretical framework for this thesis. This critical review of the literature formed the foundation for this researcher's understanding of learning, teaching, design thinking, including a review of the relevant teaching methodologies, all through the lens of Interaction Design pedagogical practice.

The literature review is divided into three main parts. The first part (sections 2.2-2.7) reviews established cognitive theories of how the process of learning is understood and how these theories have been applied to teaching, both in general and with specific application to design pedagogy. The second part (section 2.8) builds on this foundation and focusses these theories into a coherent 'conceptual framework'. The third part (sections 2.9-2.11) discusses the 'theoretical framework' of Self-determined Learning (a theory of motivation) and its influence on pedagogic engagement theory.

The objective of this research was to develop and investigate a method for augmenting Interaction Design instruction, to answer these two research questions:

Q1. Under what conditions can an Interaction Design student tacitly develop their comprehension of the design concept of problem reframing?

Q2. What is it about attempting to solve physical insight puzzles that affects the engagement of an Interaction Design student in their design studies?

2.2 Learning & Teaching

According to Pring, educational research is fraught with difficulties, despite uniform opinion that educational research must always have the same focus: how to improve learning, and thereby how to improve teaching (2004). The difficulties exist because researching education is about researching a complex series of relationships to produce actionable information. There are, and always will be, profound difficulties in reaching an understanding of the complex relationship between the teacher and student, between

the student and their peers, and especially the relationship between the student and their own mind.

In *Experience and Education*, John Dewey (1859-1952) argued that education was of such social importance that it should always be an "arena of struggles, practical and theoretical", always changing and adapting, just as the students and the society they live in changes and develops over time (Dewey 1938, p.5). He urged all educators to strive towards continuous adjustment and improvement. He acknowledged that educational policymakers had the difficult task of taking all these practical and theoretical struggles, creating a philosophy of education from them, and putting it into practice (Dewey 1986).

The field of Educational Action Research reflects the importance of education to society. Action Research's focus is to produce social change. Kurt Lewin is often credited with coining the term. He fled to the USA in the 1930s to escape Hitler's regime. His vision of action research was that it always needed to be contextualised, and desired to improve society by involving his participants in a process of fact-finding, action, and evaluation (Somekh and Zeichner 2009). It is obvious why many educational researchers also class themselves as action researchers. Education's crucial importance to individuals and society cannot be overstated, as educational experiences change an individual. They become a different person (Pring 2004).

There is a distinction between research in the social sciences that is relevant to education, and research that explicitly addresses educational issues and concerns. Critical Pedagogy scholar Paulo Freire advocated for educational practice to be empowering, that learners should go from 'the consciousness of the real' to 'the consciousness of the possible', by a learner perceiving possibilities beyond their limiting situation (Ramos 1974). Therefore, students' assignments and projects should be designed in opposition to what he called the banking concept of education, where knowledge was a gift bestowed without any acknowledgment that education is a process of inquiry (Freire 2009). Pring acknowledges that any activity can be educational, but stresses that the quality of the experience must be judged by what is being learned, judged by how that activity helps the student to make sense of things, how it leads the student to ask further questions, how it engages the student with what is before them (2004).

Two decades ago, Susan Noffke described the three different motivations for such researchers: to better understand and improve educational practice (usually their own); to produce knowledge useful to other educators; a desire for greater equality and democracy (1997). When she revisited the subject in a comprehensive review of the field in 2009, she acknowledged that there had been an impressive growth in the breadth and depth of the literature on action research, with all contributors striving to make the world a better place. But educational policy was increasingly being dictated by the ideological position that the purpose of education is to prepare individuals for the labour market. Any explicit considerations for the public interest or societal benefit were ignored by these neoliberal policies (Noffke).

In addition, Stephen Ball revealed that these policies were also having a detrimental emotional impact on educators, with their reactions to this focus on performativity being, for example:

> "I was a primary school teacher for 22 years but left in 1996 because I was not prepared to sacrifice the children for the glory of politicians and their business plans for education."
>
> "It's as though children are mere nuts and bolts on some distant production line, and it angers me to see them treated so clinically in their most sensitive and formative years."
>
> (Ball 2003)

Ball argued that this explicit commoditization of knowledge created a moral crisis for educators, with many regretfully leaving their vocation. Despite these external pressures, educational action researchers carry on regardless. However, these are not the only difficulties faced. Educational research has been fairly criticized for having a natural inclination toward the following: being too small-scale and lacking any general applicability; lacking a strong theoretical foundation; forever reinventing the wheel; being ideologically driven; methodologically soft; without any defensible rigour; written in opaque language (often to obscure all of the above) (Pring 2004).

To understand teaching, you must first understand learning. If there has been no learning, then there has been no teaching (Fosnot 2013). Any theories of how best to teach must be based on how best we learn.

2.3 Explicit & Tacit Knowledge

Explicit knowledge is knowledge that has been formally codified or structured. It can be expressed and shared through speech, writings, through pictures and/or numbers (Morgan 2008). Tacit knowledge, or implicit knowledge is usually seen as distinct from explicit knowledge (Gertler 2003).

Tacit knowledge, a term attributed to Michael Polanyi, is knowing that is mediated by showing and not by explanation (Polanyi 1966). Tacit knowledge is 'know-how', as opposed to 'know-that'. A simple example of tacit knowledge is knowledge of how tight to make a bandage; this can only be learned through personal experimentation. But Polanyi also described ways of learning tacitly that were other than direct mimicry. He used the term 'indwelling' to describe how a chess novice can learn to be a better player by playing through the games of chess masters. By such indwelling, the novice gets the feel of the master's skill. A student could "experience a man's mind as the joint meaning of his actions by dwelling in his actions from outside" (Polanyi 1966, p.14). However, Polanyi did not feel it was an either/or state. He reasoned that all knowledge has a tacit element, with only the degree of tacitness varying, and that all knowledge (including knowledge derived from established rules) was rooted in tacit knowledge (Grant 2007).

Contrary to Polanyi's perspective, research in the physical sciences (physics, chemistry, etc.) is primarily founded on a positivistic outlook, where reality is separate from the individual who observes it. According to Love, a positivistic approach is appropriate when researching these sciences (1999). There are various teaching methodologies with strict positivistic underpinnings, and they have been utilised in formal pedagogic settings. For example, the Master Learning model (Bloom 1971) assumes that when wholes are broken into parts, and skills are broken into sub-skills, then these skills can be sequenced into a 'learning line', see Figure 1 below.

$$\text{Degree of school learning} = f\left(\frac{\text{Time spent}}{\text{Time needed}}\right)$$

Figure 1 Mastery Learning Equation [1]

[1] Block, J.H. and Burns, R.B. (1976) '1: Mastery learning', *Review of research in education*, 4(1), 3-49.

A teaching system based on Behaviourism assumes that learning is a system of behavioural responses to physical stimuli (Skinner 1953). Learners are viewed as passive and in need of external motivation, assumptions grounded in Empiricist theories of learning, based on the belief that we all "hold identical objective meanings about a world we are discovering", rather than believing that we all develop our own unique understandings (Fosnot and Perry 1996, p.15).

Table 1, see below, presents a delineation of the differences between the philosophical and meta-theoretical positions of 'Positivism' and its alternate 'Interpretivism' (Weber 2004).

	Positivist	**Interpretivist**
Ontological	Reality and the individual who observes it are separate from each other.	Reality and the individual who observes it are inseparable.
Epistemological	Reality is objective and exists separate from the mind.	Reality is subjective, created through an individual's lived experiences.
Research Objects	The objects that they research have qualities that exist independent of the researcher.	The objects that they research are ascribed qualities that are socially constructed.
Research Methods	Laboratory experiments, field experiments, surveys.	Case studies, ethnographic studies, ethno-methodological studies.
Truth	A statement is true when it has a one-to-one mapping to the reality that exists beyond the human mind.	An interpretation conforms to the meaning given to it through the researcher's experience.
Validity	They collect data to measure reality. They validate the data with construct validity, internal validity, external validity, and statistical conclusion validity.	They claim the knowledge they have acquired via their research is defensible, by referring to their research methods.

Table 1 Positivist vs. Interpretivist

John Dewey criticized these positivist positions, pointing out that those who designed formal educational settings had decided on what was the correct setting for teaching, but without ever considering the students' individuality as a relevant factor, and that "this lack of mutual adaptation made the process of teaching and learning accidental" (1938, p.45). While we think throughout every moment of our lives, thinking about thinking is another matter (Lawson 2006).

Policymakers could not see that, while researching physics is the observation of inanimate objects, teaching physics is the teaching of individuals (Love 1999). Ken Robinson, in his book *Creative Schools*, wrote that a "teacher's job is not to teach subjects; it is to teach students" (2015, p.103). Reducing the student body to an element in a formula ignores the possibility that their individual perspective profoundly affects their learning and understanding.

The philosophical positions on learning that formed the foundations of both historical and contemporary pedagogic practices need to be examined, and these are discussed in the sections 2.3.1-2.3.3.

2.3.1 Constructivism & Experiential Learning Theory

Constructivism is from the field of cognitive science and initially based on the work of Jean Piaget (1896-1980), the most prominent exponent of cognitive constructivism (Piaget and Inhelder 1967; Piaget 2013). In pedagogical application, constructivism is a psychological theory of learning. Constructivism is fundamentally non-positivist, with an "epistemological view of knowledge acquisition that emphasises knowledge construction rather than knowledge transmission, where the learner is conceived as the one building and transforming knowledge" (Applefield *et al.* 2000, p.6). The focus is on cognitive development and deep understanding, rather than learning skills. The Mastery Learning model has an inherent view of learning as a linear process. While a linear process works for manufacturing processes in industry, it does not work well for those who are learning, with Robinson describing the presence of linearity in education as having created a "septic focus" (2011, p.83). A focus on linearity may make running an educational system more streamlined and more efficient, but at the cost of not actually educating the students.

Constructivists consider learning to be complex and fundamentally non-linear in nature, a naturally-occurring, automatic process (Glöckner and Witteman 2010), where there is no "objective reality since we are constructing our version of it, while at the same time transforming it and ourselves" (Fosnot and Perry 1996, p.17).

Fosnot's principles of Constructivism (2013) are as follows:

1. Knowledge consists of past constructions.
2. Constructions come about through assimilation and accommodation.

3. Learning is an organic process of invention, rather than a mechanical process of accumulation.
4. Meaningful learning occurs through reflection and resolution of cognitive conflict and thus serves to negate earlier, incomplete levels of understanding.

Constructivism was a new educational perspective, standing in opposition to Behaviourism and Maturationism (a theory that describes conceptual knowledge as dependant on the developmental stage of the learners, who are viewed as active meaning-makers). Many have confused Piaget's viewpoint with Maturationist views. Constructivism is grounded in interaction with adults and personal cognitive conflicts, whereas Maturationism is based on the idea that the student's development should be allowed without adult intervention (DeVries *et al.* 2002).

Piaget held the view that our understandings develop in childhood because of successively complex interactions with the world, always involving some type of cognitive conflict. To illustrate: a child picks up a spoon and shakes it, expecting a rattling sound because she has used a rattle before, and the shapes of the spoon and rattle are similar. This is known as *a schema*, a pattern of thought or behaviour that categorises new information and relates it to existing understanding (Burnette 2018). However, there is no rattling sound from the spoon. This creates 'disequilibrium', a conflict[2], and creates the opportunity for a cognitive change, as the attempt to assimilate the spoon into her rattle schema failed. This process always involves remembering and retrieving information, to make continuous "comparisons and judgements of similarity and difference" (Von Glasersfeld 1989, p.128), never from a tabula rasa.

It must be emphasised that when Constructivism is applied to pedagogy, it is a psychological theory of learning and not a description of teaching. Constructivism describes how structures, language, activity, and meaning making come about, emphasizing that the individual's construction of knowledge is stimulated by internal cognitive conflict as they strive to resolve mental disequilibrium. Understanding is not brought about through the transmission of information; understanding is constructed with the information (Kanselaar 2002). Learning is not the result of development; learning is development (Fosnot 2013). Constructivism describes how activity and

[2] Dewey called this moment a 'perturbation' in his 1934 work 'Art as Experience'.

meaning making interact, rather than adjusting behaviour through reinforcement (Fosnot and Perry 1996). The challenge for educators is to determine what this paradigm brings to the practice of teaching (Al-Huneidi and Schreurs 2013).

This influential theory is open to criticism. Guilford (1959) pointed out that Piaget's research methods were quite informal and his insights into learning in infancy were based on personal observations of his own three children. Guildford conceded that, considering the research subjects and the setting, this lack of rigour was understandable, and that Piaget's insights were still impressive. The most common criticism is that there is an absence of an explanation of how direct social interaction between peers and how socio-cultural and contextual factors affect cognitive development. According to O'Loughlin, while Constructivism is welcomed as an alternative to a traditional positivist perspective that teaching is the transmission of objective knowledge, it is flawed because "of its inability to come to grips with the essential issues of culture, power, and discourse in the classroom" (1992, p.1).

In Piaget's defence, he was always focussed on the individual, and his insights and theories are deliberately lacking in this regard. If socio-cultural and contextual factors affect the learning process (and surely they must) then a socio-constructivist approach is required to understand how. When Socio-Constructivism is discussed, Lev Vygotsky (1896-1934) is a prominent figure (Dimova and Loughran 2009), and this fertile area of research has continued long after his death. His contrasting perspectives to Piaget's Cognitive Constructivism are his theories about how language and thought are mediated by society. He held the anti-realist[3] position that the process of knowing involves the agency of others and is mediated by community and culture. He saw collaborative action as a mechanism that allows for the convergence of speech and practical activity. While adult social speech is often internalized as thought, Vygotsky contended that it still preserved its collaborative nature (Kanselaar 2002).

Vygotsky is also credited with the Zone of Proximal Development (ZPD), where there is an interaction on a task between a more-competent person and a less-competent person, so that the less-competent person becomes independently proficient at what was initially a jointly accomplished task. This is commonly referred to as 'scaffolding', although it was not a term Vygotsky ever used. What he did say (in Russian) was "what

[3] Realism is a metaphysical position that a reality can exist "independently of our knowledge of it" Dummett, M. (1982) 'Realism', *Synthese*, 52(1), 55-112.

the child is able to do in collaboration today he will be able to do independently tomorrow" (Vygotsky 1987, p.172).

However, educationalist Alex Kozulin asked why it was not named the 'Zone of Proximal Learning' and questioned the use of the term development (2003). While the concept of ZPD is referred to in a wide range of studies about teaching and learning, including reading, writing, mathematics, science, and second-language learning, Kozulin points out that they generally do not refer to development, only to teaching and learning. This is a reasonable point, as both theories' original focus was on the development of the child's mind, and most pedagogic practices claiming inspiration by either Piaget or Vygotsky deviated from the original concepts as they created specific applications of the theories. This thesis remains inspired by the developmental aspect of ZPD, as this pedagogic exploration aspires to help adult Interaction Design students to develop their design problem solving and to help them learn how to apply this developed thinking ability in future design endeavours, rather than just teaching them to learn a specific skill.

In contrast to Piaget's focus on individual constructions, the socio-cultural approach emphasizes the socially and culturally situated context of cognition, the social origins of cognition, how an individual's appropriation of language is a mediating tool to construct meaning. Collective actions become the focus, where "learning occurs as people participate in shared endeavours with others, with all playing active, but often asymmetrical roles in sociocultural activity" (Duffy and Cunningham 1996, p.7). Social Constructivism views the origin of knowledge construction as being at the social intersection of people, the sharing, comparing, and debating between learners and mentors (Rogoff 1990).

Constructivism has come to serve as an umbrella term for a wide diversity of views. As both Jean Piaget and Lev Vygotsky were focussed on children's cognitive development, it is a challenge to apply their theories to adolescents or adults in any pedagogic setting. To do so, there must always be an underlying assumption that, while individuals change as they continue building on an ever-increasing foundation of knowledge, the cognitive process of learning continues to function in much the same way throughout their lives. For example, Piaget identified four stages in cognitive development: sensori-motor, pre-operational, concrete, and formal. Even assuming these stages were perfect descriptions of development, children do not think like adults. Children experience a

type of egocentrism because understanding a different viewpoint from their own may be beyond them (Campbell, 2006, p. 5).

Piaget and Vygotsky (and their disciples) understood that learning was a complex cognitive process, even if what was being learned was factual by nature and the desired learning outcome was solely that the learners should understand those facts.

2.3.2 Constructivism vs. Learning Styles

Educational research findings, and not speculation, should be the basis for policy and practice (Davies 1999). An area of educational research that has both advocates and sceptics is that of Learning Styles. Constructivism's central tenet is that people construct their own knowledge by testing ideas and approaches based on their personal prior knowledge and experience. Learning Styles are "the ways learners perceive situations, understand, process, and learn information" (Eftekhar and Strong 1998, p.388). While these seem to be descriptions of similar concepts, cognitive constructivist learning is individualistic learning and socio-constructivist learning is individualistic learning mediated through interacting with others, whereas Learning Styles categorises individual learners into collective groupings. The groupings vary from model to model. The following selection of the major models of Learning Styles serves as examples (Eftekhar and Strong 1998):

1. The Myers-Briggs Type Indicator (MBTI): describes the different ways that learners prefer to receive information, and then reach conclusions.
2. The Kolb Learning Style Model: describes the different ways students perceive information or how they process information.
3. The Felder-Silverman Learning Style Model: describes how learners can be divided into five different categories. Learners are either: practical or conceptual learners; visual or verbal; inductive or deductive; active or reflective; sequential or global.
4. The Herrmann Brain Dominance Instrument (HBDI): describes learners' preferences for thinking in four different modes: cerebral left-brain thinkers; limbic left-brain thinkers: limbic right-brain thinkers; cerebral right-brain thinkers.

Education is a complex web of interconnecting strands (educational goals, educational practice, thinking, learning, cognition, emotion, motivation, engagement, etc.) and untangling it preoccupied educationalists such as John Dewey, Kurt Lewin, Jean Piaget, Paulo Freire, and Benjamin Bloom throughout their careers (Forehand 2010; Kolb 2014). Instructionism (a Positivistic approach) maintains that a single method of instruction is equally valid for 100 learners, whereas Constructivism defines those 100 learners as 100 individuals who all learn differently, their cognitive processes profoundly affected by their individual knowledge and individual experiences, even though so many life-experiences are shared. Learning Styles is an effort to untangle this educational web, being somewhere in-between these two positions. It reduces complexity by positing that individual learners can be grouped into types, so that 100 learners can become 4 or 5 groups of 20-ish, (the researcher acknowledges this is a simplification). Advocates suggest that curriculum design should be leveraging this in an advantageous way, insisting that their perspective is evidence-based and not simply the result of a desire to reduce complexity in the interests of efficiency.

However, according to John Geake, "studies of educational effectiveness of applying any of these ideas in the classroom have failed to find any educational benefits" (2008, p.1). He adds that the appeal of the idea remains undiminished, citing Coffield *et al's* review of the field the listed 170 learning style models (2004). Geake wonders why VAK[4] and other Learning Styles are so attractive to educationalists and speculates that two aspects of 'folk psychology' may have combined, (that we learn differently from each other and that we have five senses), to create a 'folk neuroscience'. Riener & Willingham go further and assert that there is no credible evidence that Learning Styles exist. They reason that it is individual ability, background, knowledge, and interest that overwhelmingly affect learning, and the focus on Learning Styles comes at the cost of attention to those factors (2010).

While subject-specific ability obviously varies from individual to individual, according to Learning Styles theory an educator should be able to improve learning performance by matching instruction to a student's learning style. But, while students do have individual preferences about how they learn, no evidence-base has been developed that shows catering to those preferences leads to better learning. If learning styles is a

[4] VAK: Visual, Auditory, and Kinaesthetic Learning Styles

neuromyth, then educators should simply continue to present information in the most appropriate manner for the content itself, taking into consideration the cohort's level of knowledge and the desired learning outcomes (Pashler *et al.* 2008; Newton 2015). The incompatibilities between Constructivism and Learning Styles will be addressed more fully when discussing the findings of this exploration.

As described earlier, a core element of Constructivism is that our understanding develops as a result of complex interactions, always involving some type of cognitive conflict. Duffy & Cunningham (1996), discussed in detail how 'cognitive conflict', or problems, could be introduced into an educational program, to become a part of the learning process:

1. The Problem as a Guide: The problem serves as a concrete reference point to focus the learner's attention.
2. The Problem as an Integrator or Test: The problem is presented after the assigned readings are completed and perhaps even after they are discussed.
3. The Problem as an Example: The problem is used to illustrate some principle, concept, or procedure.
4. The Problem as a Vehicle for Process: The problem becomes a vehicle for developing thinking skills.
5. The Problem as a Stimulus for Authentic Activity: The problem helps learners develop skills, not by being taught them directly, but by solving the problem.

It is a challenge to create a pedagogic environment that helps design students to learn how to be creative, to become a different person (Pring 2004). To meet this challenge, we should first accept that the core role of a teacher is to facilitate learning (Robinson and Aronica 2015). A second step is to regard thinking as a skill, and not a gift. If it is a skill, you can try to improve it (De Bono 1976). To create such a pedagogical environment, there must be an understanding of how students think and learn, how their sense-making process works in practical application (Donald 2002). In addition, the socio-constructivist perspective maintains that active role-playing in an essential element in learning (Duffy and Cunningham 1996). The cognitive attributes of design cognition and learning can, and should, become the content of design education (Oxman 1999).

A pedagogical possibility for achieving this is the creation of learning environments that support the application of Experiential Learning Theory (ELT). ELT is inspired by Constructivism (Healey and Jenkins 2000), where learning is conceived as being a process of the resolution of conflicts, where knowledge is created through experience (Kolb 2014). ELT describes the learning process as a recursive cycle, where students experience, reflect, think, and act.

More formally, these 4 stages are respectively labelled as:

1. Concrete Experience
2. Abstract Conceptualization
3. Reflective Observation
4. Active Experimentation

ELT provides an experience of simulated environments (Demirbas and Demirkan 2007). These experiences are a crucial element of teaching a student *how to do* (Maranville *et al.* 2015). Both Concrete Experience (CE) and Abstract Conceptualization (AC) are modes of 'grasping experience'; Reflective Observation (RO) and Active Experimentation (AE) are modes of 'transforming experience'. Students 'grasp experience' by being involved in a new experience, and then creating a theory to explain what they have observed. Students can 'transform experience' by developing observations about themselves or others and using theories to solve problems and to make decisions. Other related theories, such as Situated Learning Theory, are also inspired by Vygotsky's theories of social cognition where learning is a transaction between the individual and their social environment (Lave and Wenger 1991; Cobb and Bowers 1999; Korthagen 2010).

To apply (or discount) these educational concepts to design thinking, more specifically design problem-solving, there must be a fuller understanding of design thinking. To know how to teach design thinking, there must be an understanding of how design students learn, how they should learn to think, how they should learn "to be creative" (Robinson 2011, p.148). The following section (2.3.3) will explore design thinking and pedagogic practice for Interaction Design instructors.

2.3.3 Understanding Design Thinking

The benefits of a rationalist scientific worldview are obvious, as it has helped humans to develop advances in medicine, in communication technology, etc. However, it has also led to a division of the arts and sciences, a "narrowing of intelligence" (Robinson 2011, p.82), with academic education giving priority to ideas that can best be expressed in words and numbers. Nigel Cross, in *Designerly Ways of Knowing*, focuses on how this division has had a deleterious effect on design education, that Science and the Humanities are the two dominant cultures in formal education, with their own traditions, status and established methodologies for instruction.

While design has its own methods and ways of finding out about them, education in these three cultures consists of the same aspects.

1. The transmission of knowledge about a phenomenon.
2. Training in the appropriate methodologies.
3. An initiation into the values of that culture (2006).

These same aspects are delineated in Table 2, see below.

	Sciences	**Humanities**	**Design**
Phenomenon?	The Natural World	Human Experience	The Artificial World
Methods?	Controlled Experiment Classification Analysis	Analogy Metaphor Evaluation	Modelling Pattern-formation Synthesis
Values?	Objectivity Rationality Neutrality 'Truth'	Subjectivity Imagination Commitment 'Justice'	Practicality Ingenuity Empathy 'Appropriateness'

Table 2 The Sciences, Humanities & Design

Design, as a third culture, has been neglected and needs to further develop its own language, a language of modelling, equivalent to the sciences' language of numeracy and the humanities' literacy (Archer, 1979; Cross 1997; Cross 1999a). The core features of design ability as the abilities to:

1. Resolve ill-defined problems.
2. Adopt solution-focussing strategies.
3. Employ abductive, productive, and/or appositional thinking.
4. Use non-verbal, graphic/spatial modelling media (Cross 1990).

A problem can have a well-defined problem space; with everything you need to know to enable steady, step-by-step progress toward a solution. This is not an indicator of difficulty, and problems can still be classed as well-defined even when they are complex and have resisted many attempts to solve them (DeYoung *et al.* 2008).

An ill-defined problem is one that cannot be solved by simply collecting information and applying it directly to a solution (Cross 2001). Resolving an ill-defined design problem is "pattern synthesis, rather than pattern recognition" (Cross 2006, p.8). Designers must create a solution, not just discover what was always there.

To demonstrate the difference between synthesis and recognition, look at Figure 2, directly below. What do you see?

Figure 2 A Pile of Dots?[5]

[5] Snyder, A., Bossomaier, T. and Mitchell, D.J. (2004) 'Concept formation:'object' attributes dynamically inhibited from conscious awareness', *Journal of Integrative Neuroscience*, 3(01), 31-46.

Regardless of whether the reader has seen this image before, it is likely they ‘saw’ the Dalmatian visualised below in Figure 3, below and to the right.

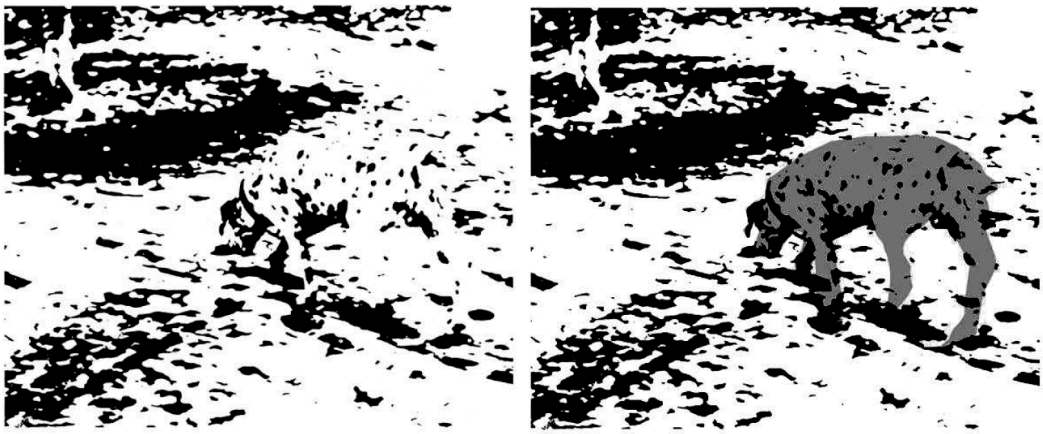


Figure 3 A Dalmation

Once you see the dog, once you find it, it becomes obvious. But this image was also shown to a South African person, who did not have a ‘mind-set’ for Dalmatians. They saw a hyena looking in a different direction (see Figure 4, below and to the right). The dots do not change for anyone. You see what you recognise, and not what you do not (Snyder *et al.* 2004).

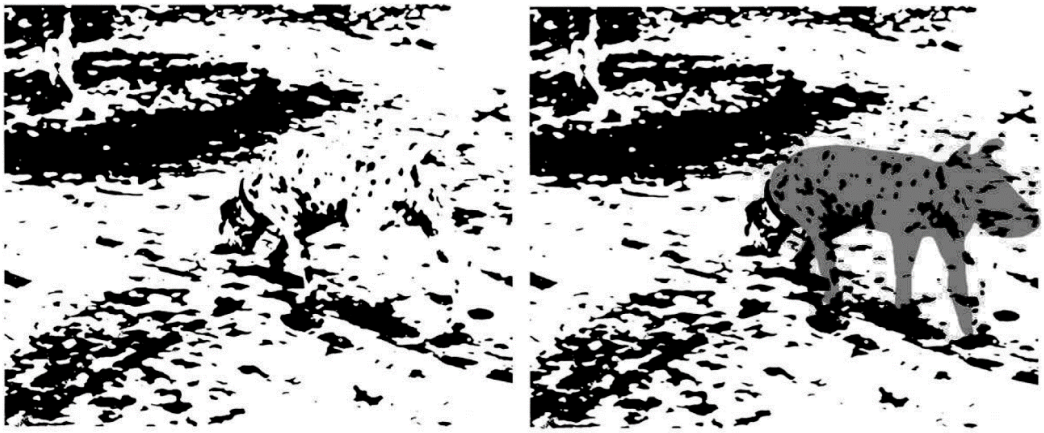


Figure 4 A Hyena

A well-defined problem suggests its own specific path to be followed; for ill-defined problems, there is no path to follow until the designer creates one.

Cross breaks down the process as follows (2001):

1. The initial representation leads to an impasse, halting progress.
2. To break that impasse, the problem representation must be restructured.
3. This restructuring leads to a rapid and complete understanding of how the solution can be reached and is often referred to as an ‘insight’.

In this context, the initial representation is the design problem. A clear path to a solution is blocked by an impasse. The initial understanding of the problem must be adjusted, restructured. It does not allow for a direct mapping of the initial problem space and it is unclear, at the beginning, exactly how to work toward a solution. There is insufficient information available to allow for incremental progress, and the problem typically requires a restructuring in how it is even approached (Webb *et al.* 2016). This restructuring, this *reframing*, paves the way for a novel solution (Martinsen *et al.* 2016; Visser 2006). Some problems are so ill-defined that Rowe described them as wicked problems, problems impossible to fully define as they are (1987). An Interaction Design student must learn how to 'restructure', how to 'reframe' an ill-defined problem.

Regarding adopting solution-focussing strategies, in *The Psychological Study of Design*, Thomas and Carroll (1979) suggested that, while a solution-based approach can be applied to well-defined problems as an alternate method, generally any problem-solving strategies are decided by the nature of the problem needing to be solved. For example, scientific problems are usually well-defined, requiring a problem-based strategy to solve. Design problems are ill-defined, requiring a solution-based strategy to solve. Bryan Lawson's studies of design behaviour (1979) compared the problem-solving strategies of designers with those of scientists by creating a 3D block puzzle, instructing both groups that they had to assemble the blocks according to pre-set rules. He discovered that the scientist group always attempted to discover the rule; the architects always focussed on the solution, see Figure 5 below.

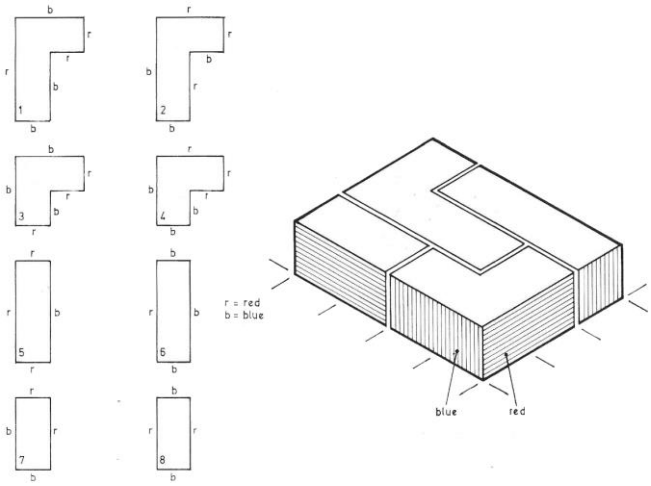


Figure 5 Lawson's Block Experiment[6]

[6] Lawson, B.R. (1979) 'Cognitive strategies in architectural design', *Ergonomics*, 22(1), 59-68.

These differences in approach to the same problem were indicative of each group's training and mind-set, rather than a considered strategy to use the 'best' method for success. This is understandable, and perhaps to be expected. But scientific problems are not the same as design problems: science examines existing forms; design creates novel forms (March 1976). Designers focus on how things ought to be (Simon 1969), and "design is the logic of conjecture", exploratory, emergent, and even rhetorical: giving the client not what they say they want, but what they need (Cross 2006, p.30). Design is ambiguous and opportunistic (Cross 1999b). A more useful system for classifying the seemingly natural division between spontaneity and calculation is to examine the study of Logic and Logical Inference.

Logic Inferences are the steps taken when reasoning. When applying logic to problem solving, the best process to be employed suggests itself when assessing both the information at hand and the objective. Deductive, inductive, and hypothetical reasoning have been formally employed throughout history (Niiniluoto 1999). Charles Sanders Peirce (1839-1914), when introducing his ideas about abductive reasoning, referred to Aristotle's (384-322 BC) explanations of inductive (*epagoge*) and hypothetical (*apagoge*) reasoning (Peirce 1992).

We employ *Inductive Reasoning* when we know the 'what' and have observable results, so working principles can be created that would explain the 'how'. If we note the initial position of stars in a constellation and we observe their position-change over time, we can develop an understanding (working principles) of how stars in the sky move. We employ *Deductive Reasoning* when we know the 'what' and already understand the 'how' (working principles), allowing us to make predictions about results. When we understand how stars in the sky move, we can deduce their future positions from their present positions. For a breakdown of the thinking behind both *Inductive Reasoning* and *Deductive Reasoning*, see Tables 3 & 4, below.

	WHAT?	**+**	**RESULT?**	**leads to**	**HOW!**
Induction	Yes, we know…	+	Yes, we see…	leads to	Understanding

Table 3 Induction

	WHAT?	**+**	**HOW?**	**leads to**	**RESULT!**
Deduction	Yes, we know…	+	Yes, we understand…	leads to	Prediction

Table 4 Deduction

Peirce is credited with advancing this logic of discovery with his writings about this concept of abductive logic (Hanson 1960). Abduction is the search for possible explanations, a strategic method of inference (Paavola 2004). Both inductive and deductive-based analytical reasoning either explain or predict what already exists. Logical Abduction is the logical basis for creative reasoning, of which there are two types.

In **Abduction-1**, we have a desired result and a set of working principles and have yet to create a 'what' (an object, a service, a system) that will produce the desired result/solution.

In **Abduction-2**, we have a desired result but no working principles, and have yet to create a 'what' that will produce the desired result/solution, see Table 5, below.

	RESULT?	**+**	**HOW?**	leads to	**WHAT?**
Abduction-1	Yes, we know…	+	Yes, we know…	leads to	Solution???
Abduction-2	Yes, we know…	+	???	leads to	Solution???

Table 5 Logical Abduction

Designers often must create a 'working principle' and develop a 'what' (the solution: an object, service, system) in parallel (Dorst 2010). This parallel reasoning, a creative double-step, requires designers to propose both a 'what' and a 'how', and test them in a co-evolutionary process (Dorst and Dijkhuis 1995). This juggling of reproductive and productive thinking is how Gestalt psychologists (Branchini *et al.* 2015) describe what happens when people face a problematical situation, identifying the two distinct thinking processes as: reproductive thinking (the logical connection between already-known chains of associations) and productive thinking (the creation of something new). Recognising that Dalmatian in the pile of dots earlier (p.19) was an example of reproductive thinking.

The concept of 'co-evolution', the development of both the problem and its solution, describes how designers develop a matching problem-solution pair by an appositional search, and not by making a propositional argument where something is either true or false (Cross 2006). This uncertainty can be stressful, but it is a skill that designers need to develop, with engineer Ted Happold admitting "I really have, perhaps, one real talent; that is that I don't mind at all living in the area of total uncertainty" (Cross 2006, p.43; Davies 1985). To ease this uncertainty, the use of non-verbal media can help an

Interaction Design student develop their capability to match a problem-solution pair. A designer employing such abilities could ease their search for possibilities as the problem and solution co-evolve. Designers are immersed in a material culture, where knowledge resides in objects. Designers need to develop the ability to both read and write in this culture, to be able to understand what an object has to say and to be able to create new objects that "embody new messages" (Cross 2006, p.21).

While the creation of design solutions can be performed in the mind alone, sketching has been widely demonstrated to be a valuable aid in design cognition. Design is ambiguous and sketching remains a key tool for supporting the exploration of tentative concepts (Cross 1999b). It enables the handling of different levels of abstraction at once, the expression of half-formed ideas to create a conceptual bridge between the problem and solution space (Cross 2001). Design ability relies fundamentally on non-verbal media of thought and communication (Cross 2006). Bill Buxton, in his book *Sketching User Experiences* describes sketching as a "vehicle, not the destination…it is the ambiguity in the drawing that is the key mechanism that helps us find our way" (2010, p.118). The ultimate objective is not to become better at sketching, but to understand something that is conceptually far more elusive (Goel 1995). This sketching is a conceptual design activity, a transaction between the designer and the representation (Oxman 1997), and remains an indispensable method of exploration for an experienced designer who is designing, and an invaluable instructional aid to a design student who is learning to design (Self and Pei 2014).

Sketching is exploratory, helping the designer to create unintended consequences, what Schön called a 'reflective conversation' (1992). For Schön, design knowledge is developed within action. The concept of 'reflection-in-action' refers to the processes by which new knowledge is developed *during* practice, where the design situation talks back, and the designer responds to that backtalk (2017). 'Reflection-on-action' refers to the active processes by which new 'knowing-in-action' is developed *after* practice (Munby 1989). Schön acknowledged that his expression 'knowing-in-action' represented an equivalent of Polanyi's ideas about tacit knowledge (1995).

This reflective conversation is a type of visual reasoning that helps the ill-behaved designer develop and discover, reject and revisit half-formed ideas, allowing the exploration of the problem and solution-space simultaneously (Hummels and Frens 2008), eventually converging on the possibility of a matching problem-solution pair

(Cross 2006). A perspective on the use of non-verbal media and materials for developing this core feature of reflexive design ability is the theory of Constructionism.

2.4 Constructionism

Piaget taught that knowledge is not a commodity to be transmitted. Nor is it information to be delivered from one end, encoded, stored, and reapplied at the other end. Instead, knowledge *is* experience, in the sense that it is actively constructed and reconstructed through direct interaction with the environment. Gagnon & Collay (2005, p.1) listed four epistemological assumptions about knowledge that are at the heart of constructivist learning, that knowledge is:

> "physically constructed by learners who are involved in active learning…symbolically constructed by learners who are making their own representations of action…socially constructed by learners who convey their meaning making to others…theoretically constructed by learners who try to explain things they don't completely understand"

Seymour Papert's Constructionism builds directly upon Piaget's Constructivism, claiming that the construction of knowledge happens remarkably well when students build, make, and publicly share objects (1991). Constructionism focuses more on the art of learning to learn, and on the significance of making things in learning. Papert is interested in how learners engage in a conversation with their own or other people's artefacts, and how these conversations boost self-directed learning, facilitating the construction of new knowledge. Papert stresses the importance of tools, media, and context in human development, differing from Constructivism in that he gives more weight than Piaget to the influence of the materials that a culture provides (Papert 1980). This aligns with Vygotsky's perspective, who stressed the mediating role of physical objects in development, and that mental processes could only be understood if there was an understanding of the tools that mediated them (Verenikina 2010).

But Constructionism shares Constructivism's view of learning as building knowledge structures through the progressive internalization of actions. Piaget's theory relates how children become progressively detached from the world of concrete objects, gradually becoming able to mentally manipulate symbolic objects within hypothetical worlds (1967). To Papert, knowledge and learning in adults remains grounded in context and

shaped by use (Terstiege 2009), where the use of physical supports remains essential for learning at any level of development (Ackermann 1991). In contrast to Piaget, Papert draws our attention to the fact that diving into situations rather than looking at them from a distance, and that connectedness rather than separation, are powerful means of gaining understanding (Ackermann 2001).

Digital Fabrication researchers share a strong constructionist perspective (Papert and Harel 1991) as they speculate on how these emerging technologies can afford opportunities for the imagining of new teaching methodologies, where the relationship between the student and the subject being studied is transformed by the making of an object (Agrawal *et al.* 2014; Loy 2014; Kostakis *et al.* 2015). The Bauhaus in Weimar was a successful example of the incorporation of the professional workshop in the academic education of architects (Naylor and Naylor 1985). Its pedagogy was rooted in the traditional apprenticeship system (Celani 2012). Oxman suggests that these new technologies should be used as a complementary method for mediating the design process (2008), that digital fabrication changes the *concept of form* into the *concept of formation*. Models can be created as an extension of the visual reasoning that sketching affords (van den Hoven *et al.* 2007), a development from the common usage of prototypes as a communication aid (Oxman 2010), as an intermediary between complex design ideas and construction workers (Sass and Oxman 2006).

There is an enthusiasm to develop a coherent foundation of understanding on how best to use these technologies in design education (Buchanan 2001; Dunne and Raby 2001; Seely 2004; Bull *et al.* 2010; Oxman 2012). A full application of these technologies could lead to new digerati: digitally literate students (Oxman 2008; Blikstein 2013). Students could then jump from digital literacy to digital *bildung*. Bildung (German for education & formation) is the process of students developing mature design abilities and a designer's mind-set, rather than a rudimentary application of learned skills with no insight (Zeising *et al.* 2013; Hjorth and Iversen 2014), a progression from technical literacy to technological competence (Blikstein and Krannich 2013).

Using physical materials to teach, to inspire, and to engage is a Constructionist approach to teaching. This thesis works within this Constructivist/Constructionist framework. But, to employ these theories into pedagogic practice is a non-trivial undertaking. Studies of how tangible interfaces, how embodied interactions can enhance learning are plentiful (Marshall 2007; Price 2008; Melcer and Isbister 2016).

Embodiment, in a tangible computing context, refers to the degree that an interaction technique conveys an impression of being a physical activity (O'Malley and Fraser 2004). Embodiment can combine digital functions to enhance our ability to represent and manage information (Wang *et al.* 2015). An example of this physical reasoning is MIT's Illuminating Light interface, where users move tangible objects on a tabletop surface for rapid prototyping of holographic layouts (Underkoffler and Ishii 1998). Embodied interaction can utilise any part of the human body, but the most obvious starting point is the hands, especially if a learner needs to build something. Hands are both a means for expression and sensation, allowing for complicated movement. Surgeons, sculptors, and musicians use their hands for the most complex of tasks but operating a computer system does not require that level of dexterity or control (Klemmer *et al.* 2006).

Current insights show that Fabrication Laboratories (Fab Labs) can empower students to accelerate ideation and invention (Mostert-Van Der Sar *et al.* 2013). Fab Labs are typical equipped with laser cutters, cnc routers, 3D scanners and printers (Gershenfeld 2008; Gershenfeld 2012) and can empower the development of students' design thinking abilities, and not just provide equipment. For example, the 'Upside-down Roller Coaster' (Blikstein 2013), see Figure 6, below.

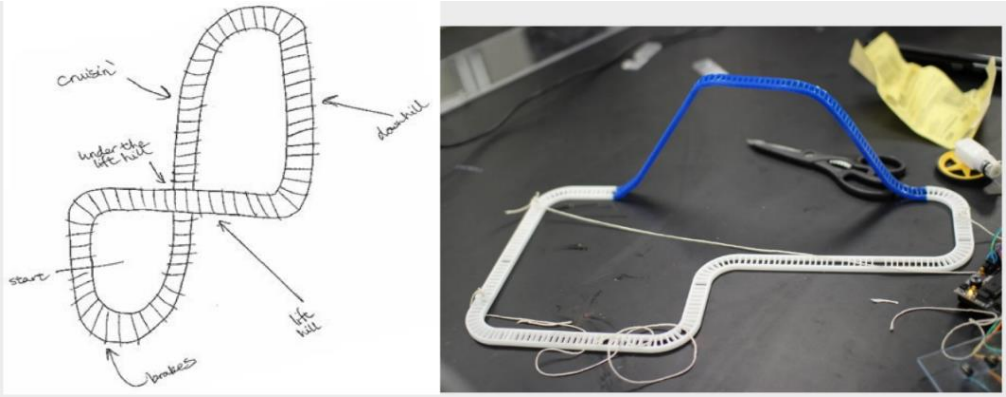


Figure 6 Roller Coaster Design 1 & 2[7]

A group of three students imagined that the Roller Coaster build process would be straightforward: design the tracks on a vector-based software, laser cut it, and assemble it. The students encountered issues with creating uniform width tracks, leading to long

[7] Blikstein, P. (2013) 'Digital fabrication and 'making'in education: The democratization of invention', *FabLabs: Of Machines, Makers and Inventors*, 1-21.

debates in the search for a solution. Their implemented solution meant that the turns were now sharper. But this was slowing down the car too much, and adding motors was not viable, and neither were any of their other ideas. Being able to build interim solutions that failed, and having those failures provide suggestions for what might work instead, eventually led to the idea of making the track go around the car, instead of having the car go around the track. They built a working prototype in just a few hours, see Figure 7 below.

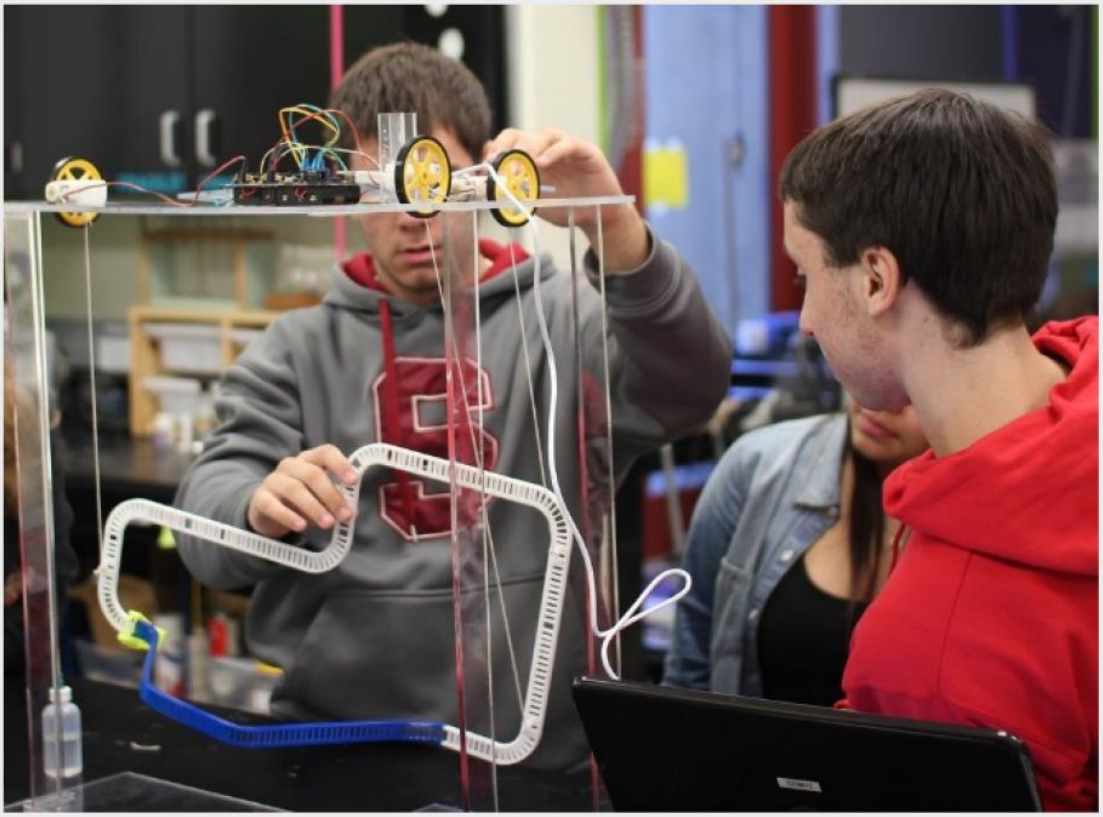


Figure 7 Learning in a FabLab[8]

They had the space and time to fail and try again, and a strong motivation to pursue their own idea, leading to a sense of achievement. Digital fabrication makes us all capable of turning "data into things and things into data" (Gershenfeld 2012, p.44).

[8] Blikstein, P. (2013) 'Digital fabrication and 'making'in education: The democratization of invention', *FabLabs: Of Machines, Makers and Inventors*, 1-21

An application of Constructionism in science pedagogy would be the work of Arvind Gupta, a toy inventor and educationalist, see Figure 8 below.

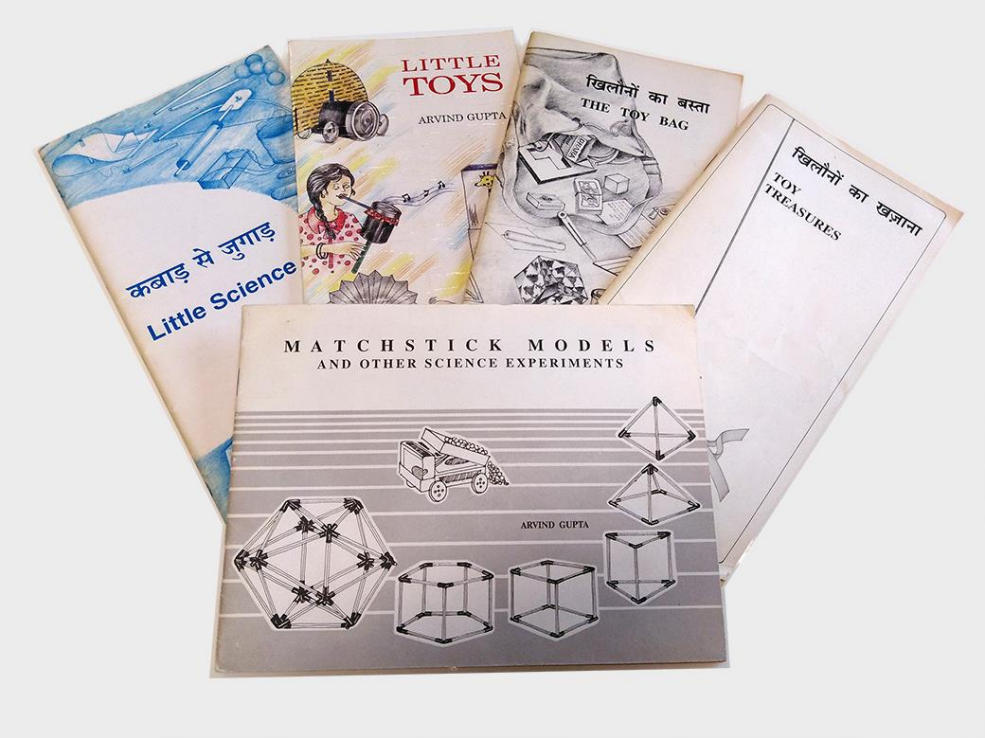


Figure 8 A selection of Arvind Gupta's books[9]

Gupta designs toys that can be easily made from local materials. He felt that the best thing a child can do with a toy is to break it (Khanna 2018), that before a child can understand something, they need experience it: to see it, to touch it, hear it, taste it, etc. They learn especially well when they can take it apart and put it together, understanding the science by learning from hands-on activities (Kirtikar 2013; Aravind 2015).

Students build simple structures that become an example of a scientific principle, such as gears, pulleys, levers, etc. It is Constructionism in action. The student is not told how important the principle is or how it works; they simply build it and by adjusting any of the available parameters, they gain a deep understanding of the principle, all the while being fully engaged in making and playing with a toy, breaking it and making it again. His toys are often just matchsticks stuck together but can be more involved if necessary. One of his more complex toys is a motor made from a rubber band, an old bicycle tube, a metal strip, a cheap ferrite magnet and a meter of wire.

[9] Image created by Author

Students can change the length of the wire and make other adjustments to see what effect this has, see Figure 9 below (Gupta 2008). These toys are also an example of increasing engagement in what could otherwise be mundane activities.

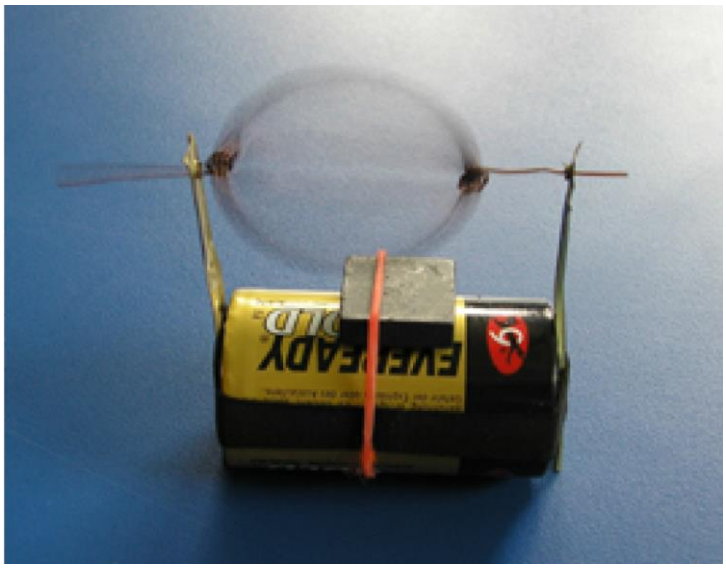


Figure 9 A Simple Motor[10]

Another method for increasing engagement in this way is the gamification of education. This is a fertile area of research, with many demonstrations of how digital games can be effective tools for teachers (Gredler 2004; Gros 2007; Nash and Shaffer 2011). Obviously, appropriate teaching plans for desired learning outcomes must remain the focus, rather than the objectives of teaching becoming servant to the restrictions or limitations inherent in a gaming system (Clark *et al*. 2016). Regarding the complexities of introducing gamification into education, Hanghøj (2011) studied the deployment of an educational game, 'Global Conflicts: Latin America'. Students were expecting a complex, open-world style of game and were generally disappointed; some were put off by large bodies of text, acceptable in a book but not in a game. The literature regarding the application of games to education can be reduced to a singular point: if an educational game is not engaging emotionally, then it loses its power to engage educationally.

To design a pedagogic environment for Interaction Design Students, a clearer understanding of the cognitive underpinnings of these pedagogic practices is necessary and this is discussed in the next section (2.5).

[10] Gupta, A. (2008) 'Learning Science through Activities and Toys'.

2.5 Divergent & Convergent Thinking

The term Divergent Thinking, credited to JP Guilford (1959), describes the production of multiple or alternative answers from available information, to generate multiple alternative problem solutions (Vincent *et al.* 2002), making unexpected combinations, recognizing links among remote associates, etc. In principle, the objective is to produce a wide variety of ideas, a large number of possible solutions. As expressed by Nobel Laureate Linus Pauling, the way to get good ideas is to get lots of ideas and throw the bad ones away (2002). In *Out of our Minds*, Ken Robinson suggests that we can learn to be creative if we have imagination and then put it to work, to develop original ideas that have value (2011).

There have always been difficulties inherent in the teaching and the externalising of design knowledge in a pedagogic setting. The Master/Apprentice system of learning eased this difficulty in the past somewhat, but these issues are exacerbated when trying to create a design language for design pedagogy in a modern industrial-scale educational system (Cross 2006). Designers can utilise several techniques to externalise their store of knowledge and experience, and to focus their creative abilities when designing. Many of these techniques or methods are also suitable for teaching design thinking when Interaction Design students are learning to become Interaction Designers.

The Design Studio, as a pedagogical system, strives to address these issues. Its origins are based on the traditions of architectural education. Students learn in the context of design projects issued by their instructor. Students express and explore ideas, generate, and evaluate alternatives, and ultimately make decisions and act in a highly social environment (Gross and Do 1997; Docherty *et al.* 2001). These projects are always hypothetical, as opposed to involving paying clients. However, even without 'real clients', this pedagogical environment is not without its pressures. The design critique[11] often deliberately puts the student in the position of having to face issues they are not yet capable of addressing. Advocates defend this activity, reasoning that the educational benefits outweigh any potential distress caused. Critics point out that 'design crits' affect some students in a detrimental way, perhaps inducing a level of discouragement that sours the relationship between student and instructor. Also, deliberately placing the

[11] A design critique refers to analysing a design and giving feedback on whether it meets its objectives.

student in the position of needing to know something but not knowing it would suggest that the instructor has created inadequate and badly structured lesson plans (Akin 2002).

Engaging students actively in the processes of constructing and presenting their own representations means that the studio-based approach aligns with both cognitive constructivist and socio-constructivist learning theories (Hundhausen *et al.* 2008). The Design Studio, with its physical environment and pedagogical strategies adjusted for an academic setting, prepares students very well for a career as an architect. But transferring this teaching methodology to non-architecture training has proved problematic (Carbone and Sheard 2002; Reimer and Douglas 2003). Despite these difficulties, as design problems are usually the most complex and ill-structured of all problems, the Design Studio is the most obvious place for design students to learn how to solve such problems in a structured environment (Jonassen and Hung 2008).

In contrast, the term Convergent Thinking is a description of the thinking process when a person is focussed on deriving the single correct answer to a clearly defined question. It emphasizes speed, accuracy, logic, and an ideational productivity (Simonton 2014). Therefore, it is most effective in situations where a ready-made answer exists and simply needs to be recalled from stored information or worked out from what is already known. The information is then applied by solving the problem with decision-making strategies (Cropley 2006). It has served as the foundation of a remarkably successful teaching methodology, Problem-based Learning in Medical Training (Jonassen and Hung 2015).

While Inquiry-based Learning is similar to Problem-based Learning (PBL), the primary difference between them is the role of the tutor. In an inquiry-based approach the tutor is both a facilitator of learning (encouraging/expecting higher-order thinking) and a continual provider of information. In a PBL approach, the tutor supports the process and expects learners to make their thinking clear, but the tutor does not provide additional information related to the problem, only the initial problem statement. It is the responsibility of the learners to find the answer.

The instructional principles for PBL, derived from Constructivism, are as follows (Savery and Duffy 1995):

1. All learning activities relate to a problem.

2. Support the learner in developing ownership of problem.

3. Design an authentic task.

4. Design the task to reflect the complexity of the environment of their practice.

5. Give the learner ownership of the process, rather than dictating the process.

6. Design the environment to challenge the learner's thinking.

7. Encourage the testing of ideas against alternative views.

8. Provide the opportunity to support reflection on the learning content and process.

PBL is a successful teaching methodology because it takes a student with domain knowledge and prepares them for professional practice. These medical trainees must digest a tremendous amount of factual knowledge (anatomy, neurology, pharmacology, pathology, etc.). Their future practice will require them to apply this mass of expert knowledge through a hypothetical-deductive reasoning process. In professional practice for medical doctors, the consequences of decisions can be life and death. Medical instructors realised that traditional lectures and access to a library did little to provide context for future clinical practice. To correct this, the first PBL curriculum was introduced at the McMaster Medical School in Hamilton, Canada in 1969, with the first European PBL curriculum introduced at the University of Maastricht, Medical School in 1974 (Barrows 1996). This novel approach was quickly acknowledged as an excellent methodology for developing critical thinking abilities in medical students.

It begins with the tutor presenting the puzzlement to the group of medical students working as a team (5-10 students). They try to solve this medical puzzle by applying their knowledge of medical facts and reasoning abilities in a setting that mimics their future professional practice. The tutor asks students the kinds of questions that they should be asking themselves to better understand and manage the problem (Barrows 1996). Eventually the students take on this role themselves, challenging each other, with the tutor continually resisting the urge to give the students direct information and guidance. This is constructivist learning in a pure form, where students participate in problem-solving and critical thinking in a learning activity that they find relevant and engaging. Their prior knowledge is leveraged against a complex problem (Karpov 2013), and then the eventual solution is integrated into their “pre-existing intellectual

constructs", improving their abilities to think critically and to reason deductively in the future (Kanselaar 2002, p.3).

Problem-based Learning, in this application, scrupulously avoids a common pitfall in education, when students ignore the instructor's planned learning outcomes and focus instead on just getting an acceptable grade (Savery 2015). The medical students, regardless of individual motivation levels, must take ownership of the problem. They must take ownership of exactly how they should work through the problem or they get exactly nowhere, all while the group dynamic propels the individual member's mental searches for the solution (Barrett 2017).

PBL is a direct mapping of constructivist principles to desired learning outcomes, a pedagogical environment where the presentation of a well-defined problem (appropriate in difficulty to the student's knowledge and abilities) supports the development of convergent and critical thinking abilities as students employ hypothetical-deductive logic. This is exactly what is required for their future professional practice.

Constructivist learning requires a puzzle to be solved, contextualised, and assimilated into existing knowledge. Disequilibrium facilitates learning, and any errors or missteps need to "be perceived as a result of learners' conceptions, and therefore not minimized or avoided" (Fosnot and Perry 1996, p.22). Medical puzzles, no matter how complex and difficult, are well-defined puzzles by nature, always focused on answering the singular question 'what is this patient's problem?' There is always a correct answer. If the trainee doctor can deduce what that problem is, it is now a matter of the correct treatment, if there is one.

Convergent and Divergent Thinking are undoubtedly useful concepts that delineate the many thinking and reasoning processes utilised in problem solving: convergent for well-defined problems that have a single correct answer; divergent for ill-defined problems with many possible solutions. A related division has been made between 'non-insight' and 'insight' puzzles, and this is discussed in the next section (2.6).

2.6 Non-Insight and Insight Puzzles

Non-insight problems, regardless of complexity or difficulty, require a convergent, deductive logic approach to solve them. This deductive analysis is a case of matching the problem with information, available or already in memory, and proceeding on the basis on that match. The initial problem statement is always clear and well-defined. The solution is simply a matter of discovering/working out the correct sequence.

The Tower of Hanoi, illustrated below in Figure 10, is an example of a non-insight puzzle. On the left is the initial state of the puzzle, the right is the completed puzzle.

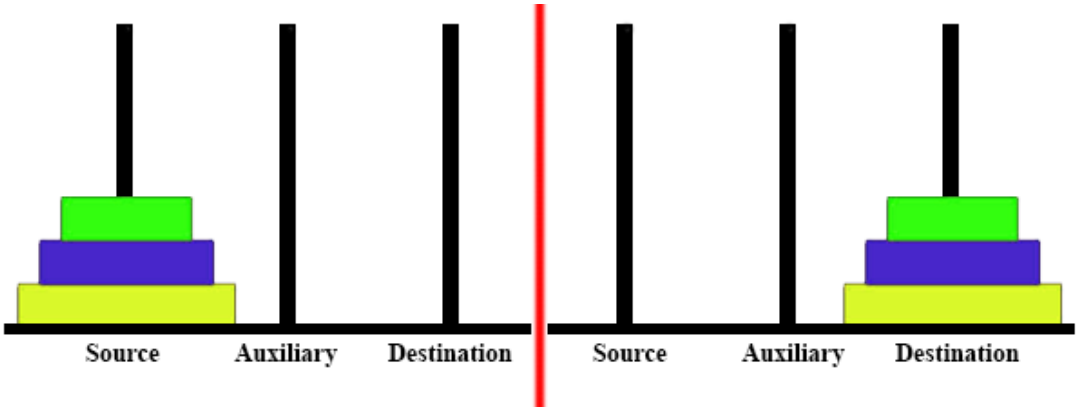


Figure 10 The Tower of Hanoi[12]

It consists of 3 rods and a number of disks of different sizes, which can slide onto any rod. The puzzle's start position is with the disks in a stack, in ascending order of size on the 'Source' rod. The objective is to move the entire stack from the 'Source' rod to the 'Destination' rod, always obeying the following simple rules: only one disk can be moved at a time; you can only move the top disk, and you have to place it either on top of another stack or on an empty rod; no larger disk may be placed on a smaller disk. The minimum number of moves required to solve the Tower of Hanoi is $2^n - 1$, where n is the number of disks. In this case, the 3 disks mean the minimum number of moves to solve is 7. The Tower of Hanoi is a non-insight puzzle. Even if you increase the difficulty by increasing the number of disks, it is the same puzzle, with the same solve patterns, requiring the same type of thinking. Increasing the difficulty does not change its classification as a non-insight puzzle. The Rubik's Cube is also a non-insight puzzle. Solving one is not easy without practice, with over 43 quintillion possible

[12] Image created by Author

permutations, but it is solvable in less than 30 moves by experts (Kunkle and Cooperman 2007). It remains a non-insight puzzle, despite its challenging nature.

The 9-Dot Problem is often presented as a classic example of an insight problem (Chein *et al.* 2010). 9 dots are presented in 3 rows; see Figure 11, below to the left.

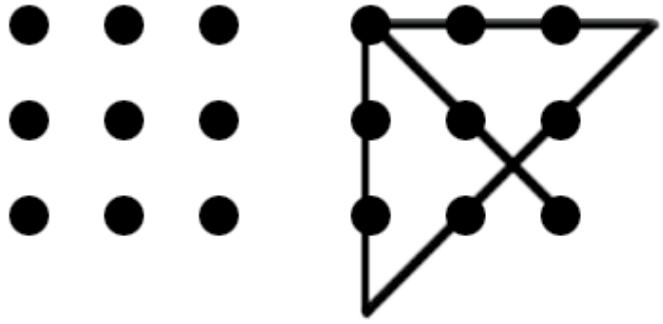


Figure 11 The 9-Dot Problem, with solution illustrated[13]

The challenge is made to draw four straight lines that go through all of the dots, without lifting the pen off the paper. After several attempts, it seems an impossible task. Most people assume you cannot extend the lines beyond the dots, as there is a natural inclination to structure the situation as a square, and so all lines must be drawn within those boundaries. This presumption makes the task impossible (Scheerer 1963). The 'Eureka!' moment comes with the realisation that you are free to draw outside the box. This is known as 'constraint relaxation' (Chu and MacGregor 2011) and is the change in perspective that makes the next step toward the solution possible (Thomas and Carroll 1979; Visser 2006; Martinsen et al. 2016). This process allows for a now obvious solution to present itself, see Figure 11 again, above and to the right (Ash *et al.* 2009).

The Insight Sequence is as follows (Chronicle *et al.* 2004; Weisberg 2015):

1. The person makes many solution attempts.
2. Little apparent progress. An impasse!
3. An event precipitates a change in the person's perspective on the problem.
4. There is a sudden realisation (Eureka!) that there can be a new way of approaching the problem.
5. This breakthrough facilitates the solving of the puzzle.

[13] Image created by Author

The most appropriate way to consider a non-insight problem or puzzle is through reproductive thinking, the transfer of knowledge of a solution from a previous problem and applying it in whole, or as a partial solution. This is an analytical process; the solution is a sequence of conscious steps. In contrast, insight problems *always* present an impasse and require productive thinking; a new understanding that can come about suddenly. But even when an individual knows ahead of time that they are facing an insight problem, there is still a natural inclination toward beginning with analytical, reproductive thinking. David Perkins suggested that if the problem resists analytic thinking, then it is time to become unreasonable, but in a smart way (2001).

It is possible to have a puzzle that requires 'insightfulness' without any impasse that blocks a step-by-step approach. For example, the 'Socks Problem' is presented as follows: Your sock drawer has white and black socks only, in a 4:5 ratio. It is dark, and you cannot see. You cannot turn the lights on. How many socks do you have to remove from the drawer to be sure of a matching pair?[14]

A complex ratio/probability calculation is not needed (Weisberg 2015). There was no impasse. Insight problems, by definition, always have insufficient information to allow for incremental progress. Insight in problem solving is associated with the sudden realization of a solution that appears obvious and correct (Gilhooly and Murphy 2005; Webb *et al.* 2016). Stellan Ohlsson suggested that there is a constant tension between one's knowledge of the world and overriding that knowledge to gain insight (2011). Insight in problem solving is also associated with the putting aside of information in memory, of "dealing with the problem almost from a naive perspective, as if one were approaching it anew" (Weisberg 2015, p.10). How this 'naive perspective' can be discovered is discussed in the next section (2.7).

2.7 Problem Reframing

The Insight Sequence is as follows: the person makes many solution attempts, but with little/no progress. There is an impasse! Then, they change their perspective of the problem, and this breakthrough facilitates the solving of the problem (Carlgren *et al.* 2016). Problem Reframing is that change in the perspective of the problem that is needed when the initial problem statement seems unsolvable. Reframing is finding a

[14] The answer is 3 socks.

new way to frame or describe the problem. A successful reframing may lead to progress toward an insightful solution. A key skill in reframing is developing the ability to recognise 'invariants', those aspects of the problem space that, on review of the problem, absolutely *cannot* be altered. Differentiating between these invariants and the aspects that, on reflection, *can* be altered is the first step in 'constraint relaxation' (Chu and MacGregor 2011). Anything that is not an invariant *may* be changed to facilitate a solution. This restructuring, this new understanding, can then pave the way for a novel solution (Thomas and Carroll 1979). While designers tend to see all problems as if they were design problems (Cross 2007), design problems do have their own identity. They are often vague, and most importantly, open to interpretation.

This interpretation and re-interpretation through framing are crucial parts of design creativity, see Figure 12 below (Self and Pei 2014).

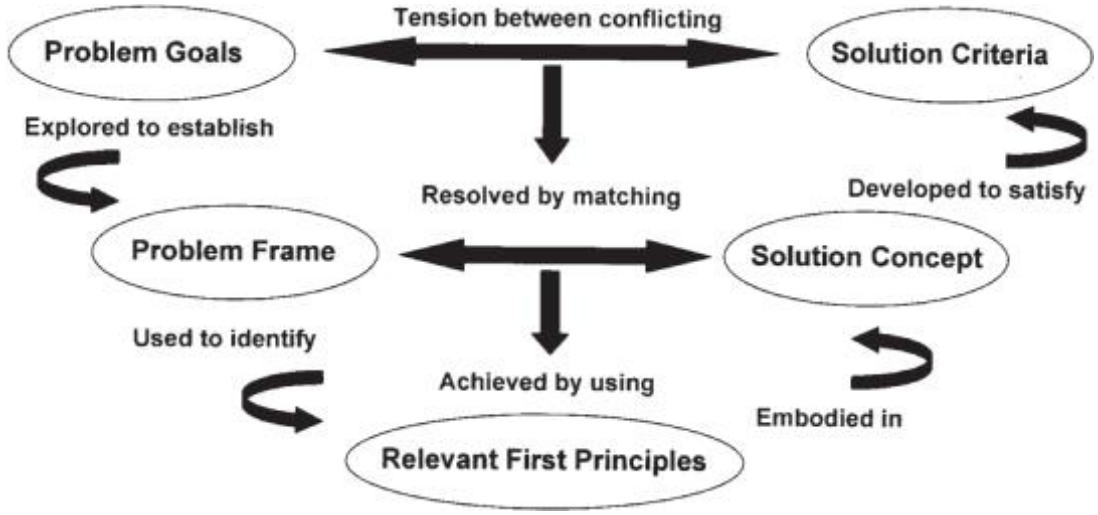


Figure 12 Reframing the Argument[15]

In relation to problem reframing, Albert Einstein is often quoted as saying that no problem can be solved by the same kind of thinking that created it. A new frame and solution conjectures to develop an understanding of the problem, as 'the problem' cannot be fully understood in isolation from 'the solution' (Dorst and Dijkhuis 1995).

Every designer faces a potential problem when problem-reframing. It is 'design fixation', the counterproductive effect of prior experience when attempting to generate a creative design to solving a problem (Jansson and Smith 1991). In practical

[15] Cross, N. (2006) *Designerly ways of knowing*, Springer.

application, it is often the opposite of reframing. Fixation can involve adding unnecessary constraints, instead of relaxing existing ones. It is important to keep in mind that knowledge can help or hinder problem solving (Smith 1995). For example, knowledge can play an important role in the resolution of analogies, but can easily exert a harmful influence, like Maslow's hammer where if the only tool you have is a hammer, you treat everything as if it were a nail (1966).

An example that illustrates reframing is the development of RADAR. The development of RADAR by Arnold Wilkins in 1935 played a pivotal role in World War 2. The process began when Wilkins, a physics graduate employed at a UK government research laboratory, was asked by his supervisor about the feasibility of a rumoured 'death ray' that the Germans may be developing. This was not as outlandish as it sounds, as many scientists around the world were claiming to be near such a breakthrough. Wilkins was asked if it was possible to use radio waves to heat 8 pints of water from a temperature of 98° to a temperature of 105° at five kilometres and a height of one kilometre (Ohlsson 2011). He failed to deliver on this design brief, to essentially build a death ray to boil German pilots. But his insights that led to radar, which played a critical role in the Battle of Britain, were based on:

1. Failing to fulfil his initial design brief (use radio waves to interfere with German pilots/aircraft), due to the laws of physics.
2. Combining his knowledge that aircraft do interfere with radio waves with a reframed brief, the *less-defined* brief of developing 'something of military strategic value'. This led to his development of RADAR, where the German aircraft's interference with radio waves made them detectable from a greater distance than before.

Wilkin's insight, his creativity, did not come out of the aether. He already had a firm grasp of how radio waves worked. He realised his initial design brief (a death ray) was completely unworkable, so he performed a 'constraint relaxation', and made a new interpretation that displayed an understanding of the true problem, the need to gain a strategic military advantage (Ash *et al.* 2009). Here, design thinking was not solely a result of divergent thinking, but a mixture of convergent and divergent thinking. Insight problem solving has three phases: an inappropriate representation of the problem; a

deductive phase that leads to impasse; a post-impasse restructuring phase (Ash and Wiley 2006). Wilkin's RADAR was the product of 'design thinking' that was based primarily on analytic thinking, the application of knowledge and deductive reasoning, both before and immediately after the reframing of the argument.

Furthermore, Emily Nusbaum and peers argue that the traditional division between convergent and divergent thinking may not be as clear-cut as often observed in the literature (Guilford 1967). She provocatively asked 'does a person have to be smart to be creative?' and then takes the position that there may be a stronger link between creative cognition and intelligence than the traditional viewpoint that they are separate areas of cognition (2011). If those who come up with creative ideas do so because they successfully use convergent processes, then divergent thinking may be more convergent than creativity research acknowledges (Nusbaum and Silva 2011). Perhaps few real-world tasks require exclusive convergent or divergent thought, even though the distinction has proven itself useful, being a foundational element of the design of PBL in Medical Training (Guilford 1967; Lawson 2006).

While the conscious mindset for 'insight problem-solving' is different from 'problem-solving through analysis', Bowden suggests that this does not mean that the underlying processes are different (2005). Arthur Koestler labelled the flash of insight that bridges between two previously separate domains as 'biasociation'. He went as far as claiming that all forms of creativity were driven by this mechanism (1964) where you experience several thinking processes at once. The 'special-process view' (from Gestalt theory) proposes that the 'insight sequence' is triggered by reaching an impasse. In contrast, the 'business-as-usual view' argues that analytic thinking brings about insight. Although these views are often presented as mutually exclusive, perhaps a complete understanding of insight will require bringing them together into a new theory of insight (Fleck and Weisberg 2004; Batchelder and Alexander 2012; Weisberg 2015).

In *Does Insight Problem Solving Predict Real-World Creativity?* a rather tangled position is presented (Beaty *et al.* 2014a). This review paper of creativity testing explains how the testing of divergent thinking abilities has a long history and has proven a reliable predictor of creative performance in testing. This despite an earlier paper where the same research group suggest that divergent and convergent thinking may not be the distinct processes as is generally believed (2011). The authors of this 2014 paper suggest that there is a lack of evidence to claim that insight problem solving relates to

real-world creativity. For their testing process, they used the Remote Associates Task (RAT); where a series of three seemingly unrelated words are presented (e.g., rat; blue; cottage), and the subject is required to find a fourth word that could link them all. Here, 'cheese' is a satisfactory answer (Mednick 1962).

They also used several examples of The Contradictory Statement[16]; where a situation is presented but seems nonsensical/impossible. Subjects must reframe the situation to explain the inherent contradictions. For example, a man in a town married 20 women. He and the women are still alive, and he has had no divorces or annulments. He is not a bigamist (meaning he is not legally married to more than one woman at once) and has broken no laws. How is that possible? The answer is that he is a priest.

Based on this type of testing, this group also analysed different methods of presenting such results in a meaningful way (Silvia *et al.* 2009a; Silvia *et al.* 2009b). This researcher found their reasoning, conclusions, and their studies contradictory. Researchers employing the RAT test suggest that it is divergent thinking that creates the answer. However, as the answer must be derived from memory, then this is a result of convergent thinking. It is fair to acknowledge that using 'The Contradictory Statement' does require subjects to 'reframe' the situation to resolve them, and so has instructional value for helping students to understand the concept of 'reframing'.

However, the same research group also explained 'controlled attention theory', a goal-directed, top-down approach theory of creative idea production (Beaty *et al.* 2014b). They refer to the classic 'Alternate Use Test', where participants are asked to generate alternate uses for common objects (e.g., a brick). 'Controlled Attention' is required to inhibit obvious suggestions such as 'build a house with it' so that subjects can be more imaginative. They concluded that the creative process might have more to do with analytic thinking than previously accepted. This researcher is in agreement with them here, and with Lee and Therriault, who suggested, "a common cognitive process in divergent thinking and convergent thinking may be reliance upon some form of associative processing" (2013, p.3), where analytic thinking and creative thinking are distinct processes, and yet somehow not distinct from each other.

[16] "The Contradictory Statement" is a collective term coined by the Researcher, for convenience.

2.7.1 Constructionism in Insight Problem Solving

Vallée-Tourangeau et al. conducted an experiment to test whether the same puzzle, if presented in two different ways, would produce different rates of completion/success (Steffensen *et al.* 2016; Vallée-Tourangeau *et al.* 2016). The experiment was run twice, with variants. The puzzle was 'How do you put 17 animals in 4 enclosures in such a manner that there is an odd number of animals in each of the four pens?'

Test 1: All 50 participants were given a pen and paper for 3 minutes to sketch ideas for possible solutions. After an interval (25 minutes), they were separated into 2 groups and given an additional 10 minutes. Group A (n=24) was invited to sketch a solution using a stylus and an electronic tablet. In that condition, no artefacts could be manipulated to spark ideas as participants drew their solution of the problem on the tablet. Group B (n=26) was given artefacts to build a model of the solution. They could not sketch a solution using a pen; only the material with which to build enclosures and 17 animal figurines were provided, see Figure 13 below.

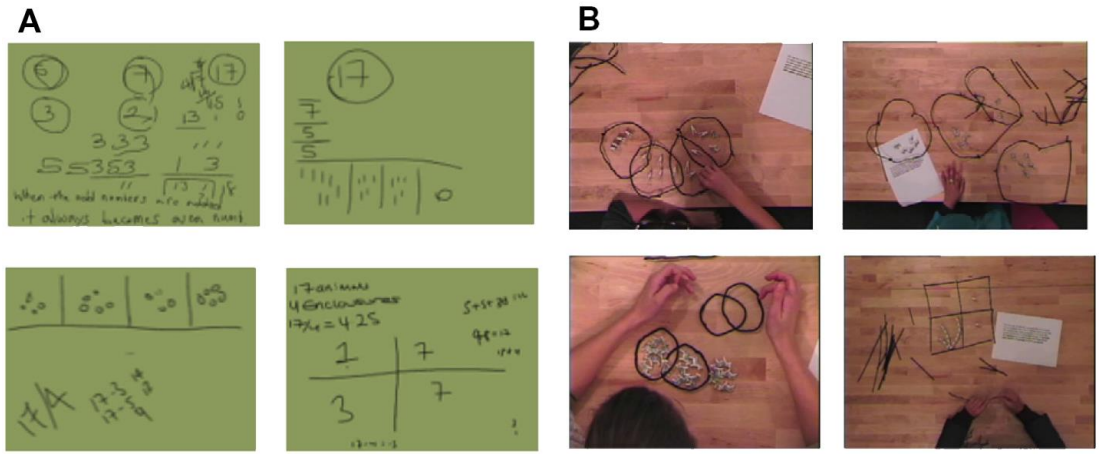


Figure 13 Tablet (A) & Model (B)[17]

No participants solved the problem within the 3 minutes of sketching. No one from Group A (stylus & tablet) solved it in the end. From Group B, 10 did not solve, but 7 created a partial solution and 6 solved the problem outright (3 of the unsuccessful attempts were discounted, an administrative failure).

[17] Vallée-Tourangeau, F., Steffensen, S.V., Vallée-Tourangeau, G. and Sirota, M. (2016) 'Insight with hands and things', *Acta psychologica*, 170, 195-205.

Test 2: Group C (n=23) was invited to sketch a solution using a stylus and an electronic tablet. Group D (n=24) was given artefacts to build a model of the solution.

There was no sketching phase for all participants, see Figure 14 below.

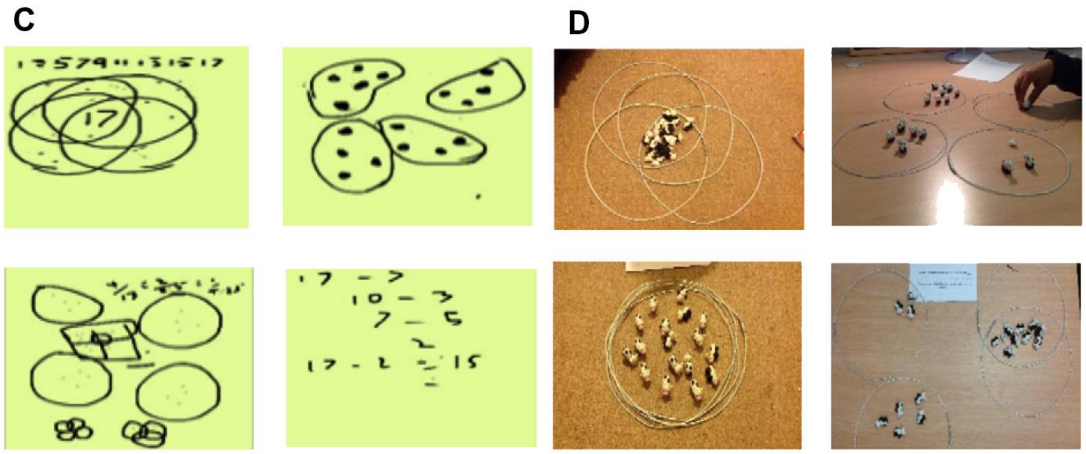


Figure 14 **Tablet (C) & Model (D)**

4 participants from Group C (stylus & tablet) solved the puzzle. From Group D, 13 created a solution.

Findings from this experiment were two-fold. In both experiments, participants were more likely to develop a working solution in the model building condition. The common sketching phase in the first experiment affected the results significantly. Sketching at the beginning seemed to reinforce it as the correct method for finding a solution, for Group A (stylus and tablet) at least. Without this phase, Experiment 2 produced more successes from the stylus and tablet group.

The problem masquerades as an arithmetic one, but an arithmetic solution is impossible (with whole animals/numbers). A mathematical solution is possible, where the pens are projected as Sets that can overlap, therefore a reframing is necessary to solve it. In both experiments, the ability to physically manipulate the puzzle elements contributed to higher success rates, as it made the reframing of the initial problem statement much easier (Vallée-Tourangeau *et al.* 2015).

An interesting point is made by these researchers, that materiality matters. The properties of the pipe cleaners guided the problem solver along a certain path. This material engagement created chance configurations, leading to a solution. This is not a new understanding, as Norman Maier's pendulum problem from 1931 demonstrates

(Maier 1931; Dix 2009). Maier attached two cords to the ceiling of his lab and asked participants to tie the two ends together. The two cords were far enough apart so that if you held one cord, you could not reach the other. As a hint, Maier would 'accidentally' brush off a cord. The swinging motion would prompt the solution of swinging one cord, then grabbing the stationary one and catching the swinging cord when it swings back toward you. These researchers stress the point that when we are thinking manually, when we are thinking by using our hands (or any other body extremity), then we are thinking differently from when we stare into space, contemplating.

2.8 Conceptual Framework

This section distils the pedagogic theories and practices discussed in the literature review into a conceptual framework that will be the foundation for this research's pedagogic exploration. The domain for this research is Interaction Design pedagogy, specifically problem solving. The type of design problems that Interaction Designers face are not well-defined; they are ill-defined (Jonassen 2000). The ability to solve these types of problems is a core feature of design ability. To address this, a design pedagogic environment should present opportunities to: resolve ill-defined problems; adopt solution-focussing strategies; employ abductive/productive/ appositional thinking; use non-verbal, graphic/spatial modelling media (Cross 2006). The Design Studio provides an appropriate environment for this pedagogic practice, where instructors combine discourse, example, and demonstration (Jonassen and Hung 2008).

The distinction between explicit knowledge and tacit (implicit) knowledge (Gertler 2003) is that explicit knowledge can be mediated through speech, writing, pictures, and numbers, whereas tacit knowledge is mediated by demonstration and gained through personal experience (Morgan 2008). But learning tacitly is more than just mimicry. Polanyi used the term 'indwelling' to describe how a chess student could experience the mind of a chess master by playing through an exemplary game (Polanyi 1966). In addition, Polanyi did not feel it was an either/or state but reasoned that all knowledge was rooted in tacit knowledge to varying degrees, even including knowledge derived from rule-based sciences (Grant 2007).

Constructivism describes how people construct knowledge by testing new knowledge against prior knowledge and experience and integrating this "new knowledge gained

with pre-existing intellectual constructs" (Kanselaar 2002, p.3). Learning occurs in the attempt to reconcile the discrepancy when expectations are not met.

Therefore, a generic application of Constructivism to pedagogy would be a setting that provides a cognitive conflict or puzzlement, and where the student's reconciliation of this conflict is the desired learning outcome of the lesson. This has already been accomplished in science pedagogy with an inquiry-based approach to learning where a question is answered by gathering and understanding new knowledge, with a reflection on this new knowledge (Savery 2015). Constructivism is also a foundational element of Experiential Learning Theory, a theory of teaching where learning is a process of resolving conflicts and tacit knowledge is created through experience (Healey and Jenkins 2000). The process is a recursive cycle, where students experience, reflect, think, and act (Kolb 2014). Constructionism, directly inspired by Constructivism and theories of tacit knowledge, claims that knowledge construction is accelerated when students build objects (Papert 1991). The earlier example of the roller coaster (p.27) demonstrated that the ability and freedom to build exploratory, interim solutions facilitated learning as any failures gave feedback and helped guide insight as to what could be improvements to the design of their roller coaster.

To align these theories into a coherent conceptual framework for this research, the focal point is the resolution of ill-defined design problems. Solving these ill-defined design problems is achieved through what is known as the 'Insight Sequence', which is as follows (Chronicle et al. 2004; Gilhooly and Murphy 2005; Weisberg 2015):

1. The person makes many attempts to solve.
2. They reach an impasse!
3. The person's perspective on the problem is changed.
4. There is a sudden realisation of a new way of approaching the problem.
5. This breakthrough facilitates the solving of the puzzle.

Step 3, the change in perspective, is commonly called 'reframing' (Dorst 2015). Reframing is finding a new way to frame or describe the problem so that a solution is now possible. A key factor is developing this ability to reframe is to be capable of recognising the difference between 'invariants' (aspects of the problem which *cannot* be altered), and aspects that *can* be altered.

But there is controversy regarding the types of thinking required to solve these distinct types of problems. Some researchers claim that solving ill-defined problems by divergent thinking alone is too simplistic, but that alternating between both divergent and convergent thinking better describes this process (Ohlsson 2011). Other researchers feel that even making a distinction between the thinking processes themselves is simplistic (Nusbaum and Silva 2011).

But, thinking in terms of a division between convergent and divergent thinking was a foundational element of Problem-based Learning in Medical Training (Savery and Duffy 1995). Table 6, see below, presents a delineation of PBL in Medical Training and its equivalent in Design Training.

All learning needs a puzzle	**Medical Training**	**Design Training**
Type of Problems?	Well-defined Problems	Ill-defined Problems
Type of Strategy?	Problem focussed	Solution focussed
Type of Thinking?	Deductive/Reproductive	Abductive/Productive
Media Used?	Verbal/Internalised	Non-verbal/Externalised

Table 6 Medical vs Design

What remains uncontroversial is that pedagogical Constructivism needs a 'puzzlement' (Duffy & Cunningham 1996) and that Constructionism states that interacting with physical objects accelerates tacit learning (Papert 1991). To aid design cognition, the physical and cognitive activity of sketching is an established tool that supports the exploration of tentative concepts (Cross 1999b), helping the designer focus on the expression of half-formed ideas (Cross 2001), where the ambiguity in the expression of such ideas can guide the way to a solution (Buxton 2010). Schön described sketching as a reflective conversation (1992). His concept of 'reflection-in-action' describes how new knowledge is developed *during* practice, an equivalent of Polanyi's tacit knowledge (Schön 1995). Interaction Design students need to practice solving ill-defined problems (Cross 2006); and that there is an equivalence between 'ill-defined problems' and 'insight puzzles' regarding the similarity in the approach needed to solve them (Weisberg 2015).

A pedagogical approach to explore these concepts could present an ill-defined design problem to students, (an 'insight puzzle'), which could have multiple valid solutions. To solve it, they would need to exercise abductive reasoning while managing that

alternation between both divergent and convergent thinking, When the problem resists analytic thinking, they would then have to exercise abductive reasoning (Perkins 2001).

The conceptual framework derived from this literature review suggests the following criteria for a simulated pedagogic environment that could explore the issues raised:

1. An environment that presents opportunities for design students to: resolve ill-defined problems; adopt solution-focussing strategies; employ abductive thinking; use non-verbal, graphic/spatial modelling media.
2. It must be as logically coherent as PBL is for Medical Training, i.e., to help students develop tacit knowledge by helping them learn to think like Interaction Designers and not just be repositories of information.
3. As Constructivist learning requires a puzzle to be solved, to be contextualised and then assimilated into existing knowledge, insight puzzles would have to be created that are more than just clever word games, or association tests that have right or wrong answers.
4. A Constructionist perspective requires tangibility. Therefore, the puzzles will be tangible. This will have the dual benefit of exploring a theoretical position and allowing for a visible externalising of the participant activities.
5. The setting should allow for investigating the idea that 'creative thinking' in design is a path from Convergent (deductive) Thinking, to Divergent (abductive) Thinking to get over an impasse, then immediately back to Convergent Thinking until the solution is finalised.

The theoretical framework for this exploration is now discussed, in section 2.9.

2.9 Theoretical Framework

The theoretical framework for this thesis is Self-Determined Learning (SDL). This is a theory of motivation based on cognitive psychology that is also a foundational element of pedagogical engagement theory. When applied in an educational context, its purpose is to promote an interest in learning, to instil confidence in learners' own capabilities (Deci *et al.* 1991).

It is necessary to delineate motivation and engagement, both to understand the issues and to express any research findings with clarity.

The delineation is as follows:

1. Motivation is the direction and intensity of one's activities (Maehr and Meyer 1997), answering the question of "why am I doing this?" (Appleton *et al.* 2008, p.11).
2. Engagement is the behavioural "intensity and emotional quality of a person's active involvement during a task" (Reeve *et al.* 2004, p.147).

Motivation and Engagement are separate but not fully independent—one could be motivated but not actively engaged in a task (Connell and Wellborn 1991; Furrer and Skinner 2003). Motivation is thus necessary, but not sufficient for engagement. For example, a design student may love studying design, and therefore is highly motivated to study design in a general sense. They may be fully engaged in modules directly dealing with design but less engaged with their mathematics module, despite understanding its relevance to their development as a designer. Motivation is an attitude that is much more general than Engagement. Engagement must always be subject specific.

As with Constructivism, Motivation & Engagement theories are also not theories about teaching, but they do provide a framework that a pedagogic practice can be measured against. Self-determination Learning theory (SDL) is a macro-theory of human motivation, personality development, and well-being (Ryan 2009). The theory focuses on self-determined behaviour and the social conditions that promote it. SDL also proposes that the fulfilment of the psychological needs of competence, relatedness, and autonomy are essential (Deci and Ryan 2008).

SDL's formal framework is made up of the following theories:

Cognitive Evaluation Theory (CET): This describes how social contexts and interpersonal interaction either facilitate or undermine Intrinsic Motivation (doing something for its own sake, e.g., sports, music, leisure). Autonomy and competence are crucial elements in Intrinsic Motivation, and a lack of opportunity for them will diminish Intrinsic Motivation. For example, deadlines, rewards or punishments and any other similar pressures can undermine Intrinsic Motivation. CET explains why some reward structures can detract from motivation (Deci *et al.* 1999).

Organismic Integration Theory (OIT): This describes the internalization of various extrinsic motives. This regulation of the three types of internalization, (which can occur simultaneously), is facilitated by supports for competence, relatedness, and autonomy.

Causality Orientations Theory (COT): This describes how individuals focus on different aspects of their environment when regulating their own behaviour. When they are autonomy-oriented, they focus on what interests them. When control-oriented, they focus on social controls and rewards. When impersonally oriented, they focus on any lack of control or competence.

Basic Psychological Needs Theory (BPNT): This describes how an individual's behaviour, or an event, affects their well-being and is directly related to their needs being satisfied.

Goal Contents Theory (GCT): This describes how materialism and other extrinsic goals, even if achieved, do not foster well-being. In contrast, personal goals such as intimate relationships and helping others facilitate wellness.

Research has shown that autonomous motivation predicts persistence and adherence and is advantageous for effective performance, especially on complex or heuristic tasks that involve deep information processing or creativity (Amabile 1979; Sheldon 1995; Hennessey 2000). The topic of motivation concerns what moves people to act, think, and develop. The central focus of motivation research is therefore on the conditions and processes that facilitate persistence, performance, healthy development, and vitality in human endeavours.

Traditional motivational theory focuses on Intrinsic and Extrinsic Motivation. Intrinsic Motivation involves engaging in an activity because the activity itself is interesting and spontaneously satisfying. Extrinsic motivation, in contrast, involves engaging in an activity because it leads to some separate, desired consequences or rewards.

Self-determined Learning theory (SDL), when applied in an educational context, is "concerned primarily with promoting in students an interest in learning, a valuing of education, and a confidence in their own capacities and attributes" (Deci and Ryan 1985; Deci *et al.* 1991, p.325). SDL differentiates motivation, with autonomous and

controlled motivations being the key distinction. The type of motivation is generally more important than the amount in predicting important outcomes (Deci *et al.* 1991).

Autonomous Motivation involves behaving with a full sense of volition and choice, whereas Controlled Motivation involves behaving with the experience of pressure and demand toward specific outcomes that comes from forces perceived to be external to the self. Both Autonomous and Controlled Motivation energize and direct behaviour, in contrast to Amotivation. Autonomous Motivation is based on a deeply reflected endorsement of one's behaviour. When feeling autonomous, people perceive that their behaviour emanates from the self, and they act because they find interest in or are challenged by the experience of the behaviour, or because there is a personal meaning in what results from it. The predominant feeling is 'wanting to'.

By contrast, with Controlled Motivation, the predominant feeling is pressure, which is often associated with ambivalence. The pressure or controls that regulate the behaviour can either stem from external rewards or demands, or internal pressures such as guilt, shame, or pride. Expressions such as 'must' and 'should' are typically associated with this form of motivation (Ryan and Deci 2000).

However, an issue with the literature regarding motivation and engagement is that those terms are used interchangeably and inconsistently (Sinatra *et al.* 2015). These difficulties have arisen in the attempted development of a 'Theory of Engagement'. Roger Azevedo pointed out that his search of "the literature on PsycINFO yielded more than 32,000 articles about engagement in the last 14 years" (Azevedo 2015, p.84). There are definitional issues throughout, a lack of consistency regarding specification of theoretical underpinnings. The term engagement has become meaningless by itself, with each author having to qualify exactly what they mean by the term. Azevedo claims that no one adheres to a theory of engagement because there is none, with no consensus on the conceptual foundation (Fredricks *et al.* 2004; Burch *et al.* 2015; Boekaerts 2016). These issues are understandable, naturally arising as researchers have developed our knowledge and understanding of cognition, learning, teaching, and motivation. These issues are compounded when trying to combine them all into coherent theories of motivation and engagement.

SDL asserts that student engagement is predicated on enthusiasm (Reeve and Tseng 2011). The level of enthusiasm in a classroom environment is often based on the

instructor's personal ability to enthuse, rather than anything else. This personal ability to enthuse is considered as separate from the instructional content (Rosenshine 1970), and is often labelled as charisma by researchers, and made up of behaviours such as "immediacy, humor, caring…self-confidence, energy…friendliness and care for others" (Bolkan and Goodboy 2014, p.136). It is a central trait that influences a student's evaluation of a lecturer (Shevlin *et al.* 2000). While exhaustive evidence-based studies consistently demonstrate the value of teaching charisma (Huang and Lin 2014), there is a possibility of this being problematical for any Inquiry or Problem-based Learning approach. In *Taking the Charisma Out: Teaching as Facilitation*, Joseph Raelin, relating his own experiences, cautioned that there is a danger of the charismatic teacher accidentally reducing themselves to being a transmitter of learning, rather than being a facilitator; and that while the students may be more interested in what an interesting teacher has to say, there is a risk that they will accidentally become dependent on being spoon-fed, and not develop the critical thinking abilities needed to solve problems by themselves (2006), developing dependency instead of self-directedness (Knowles 1980).

2.9.1 SDL: Competence, Relatedness, Autonomy

Deci & Ryan's Cognitive Evaluation Theory (CET) specifies the factors in social contexts that can affect variability in Intrinsic Motivation, arguing that rewards, communications, and feedback that encourage and induce feelings of competence can enhance intrinsic motivation for that action (Deci and Ryan 1985). To apply self-determination theory in an educational context, an institution should provide an environment that supports the development of the following (Silva *et al.* 2014):

1. **Competence:** This is the understanding of how to attain various external and internal outcomes and being, or at least feeling, effective in performing the requisite actions.
2. **Relatedness:** This involves developing secure and satisfying connections with others, feeling understood and cared for by others.
3. **Autonomy:** This refers to being self-initiating and self-regulating of one's own actions, the feeling of being the originator of one's behaviours.

Individuals are more likely to internalize and integrate a practice or value if they experience efficacy in engaging in it, have a connection with those who convey it, and choices with respect to it. Educators can facilitate student self-determination with extrinsically motivated tasks by leveraging relationships, setting up students for success in course tasks (via scaffolding of lessons and attention to developmental level), and orchestrating student opportunities for decision-making and other authentically autonomous experiences (Deci *et al.* 1991).

SDL theory is built around the concepts of Introjection, Internalisation & Integration. SDL theory does refer in passing to Intrinsic Motivation. Some behaviours are intrinsically motivated, defined as "activities that interest them, and they do so freely, with a full sense of volition and without the necessity of material rewards or constraints" (Deci *et al.* 1991, p.328). While it is possible for some academic pursuits to be classed as intrinsically motivated, this is generally not the case, no matter how interesting the subject matter. In theoretical argument and in practical application, there is a reasonable presumption that educational pursuits will always be extrinsically motivated. To allow for practical discussion about how to help a student move towards intrinsic motivation, Self-determined Learning focuses on extrinsic motivation, and that the 'internalization' of extrinsic motivation is a three-step process.

1. The least effective type of internalization is referred to as 'lntrojected Regulation'. This involves people taking in an external contingency, demand, or regulation but not accepting it as their own.
2. The next type of internalization is referred to as 'Identified Regulation'. This involves people accepting the importance of the behaviour for themselves and thus accepting it as their own.
3. Finally, the most effective type of integration internalization is referred to as 'Integrated Regulation'. This involves people succeeding at integrating identification with other aspects of their true or integrated self.

As Self-determined Learning focuses its attention on Extrinsic Motivation and Amotivation, successful application of the theory is ultimately the helping of a learner to progress through the stages of Extrinsic Motivation, from 'external regulation', to

'introjected regulation', to 'identified regulation', to 'integrated regulation', while helping them avoid Amotivation during the process, see Figure 15, below.

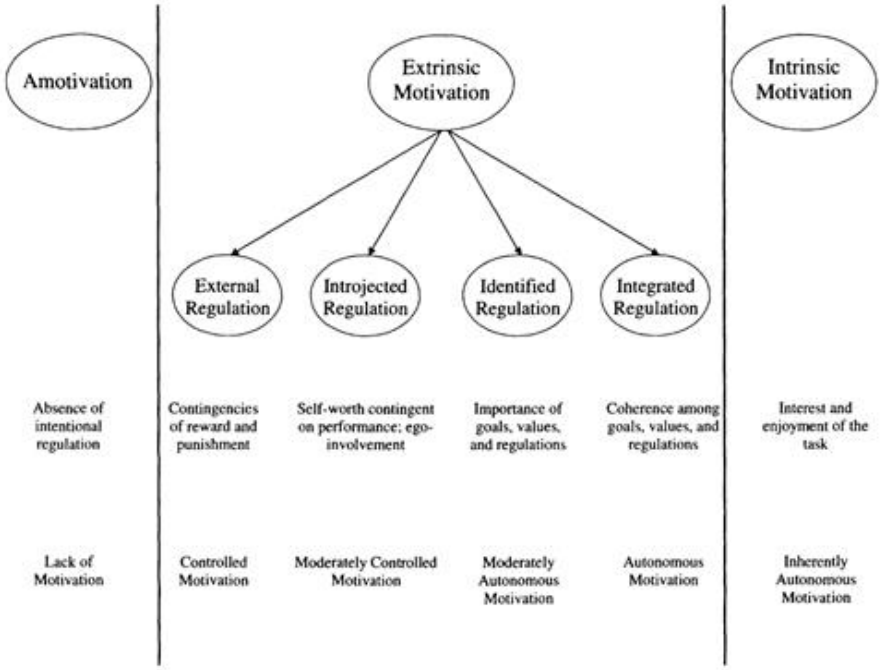


Figure 15 Self-Determined Learning Theory[18]

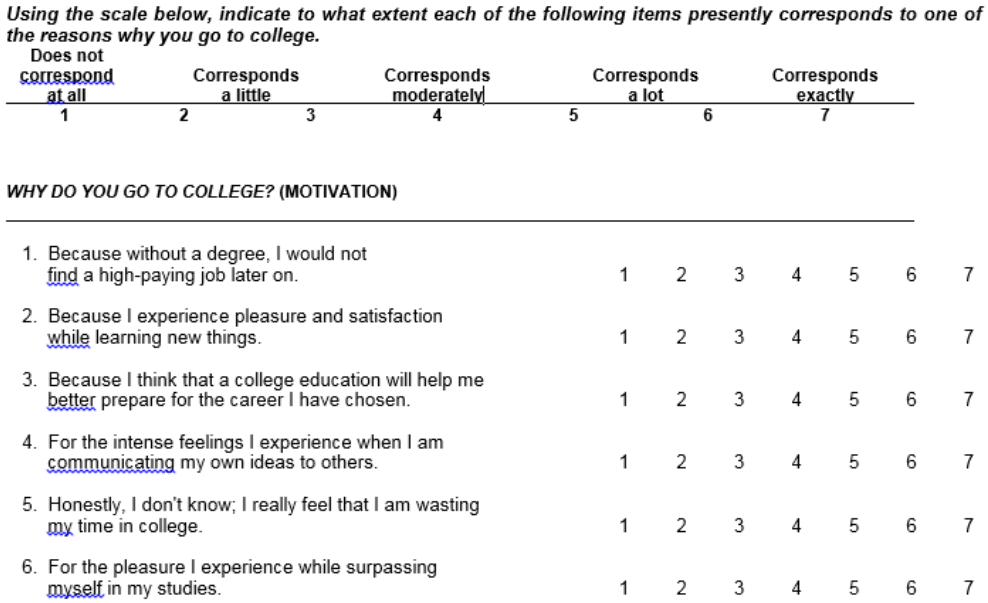
SDL theory is a cognitive theory of motivation that states that if an educational program can provide support for the personal development of: Competence (to become efficacious); Relatedness (personal relationships); and Autonomy (self-direction), then this will encourage students to persevere in their studies and help prevent Amotivation. How to apply the theory will always depend on the subject matter being taught. Measuring Motivation and Engagement is discussed in the next sections (2.10-2.11).

2.10 The Academic Motivation Scale: A Quantitative Measure of Motivation

The Echelle de Motivation en Education (EME) is a quantitative measure of motivation (Vallerand *et al.* 1992). Its theoretical foundation is in Self-determined Learning theory. In English, it is called The Academic Motivation Scale (AMS). The AMS is a tested, robust Likert-style scale (Fairchild *et al.* 2005), composed of 28 items subdivided into 7 sub-scales, assessing 3 types of Intrinsic Motivation; 3 types of Extrinsic Motivation;

[18] Deci, E.L. and Ryan, R.M. (2008) 'Self-determination theory: A macrotheory of human motivation, development, and health', *Canadian psychology/Psychologie canadienne*, 49(3), 182.

and Amotivation by asking “Why do you go to college?” and providing 28 statements, see Figure 16 below.



Using the scale below, indicate to what extent each of the following items presently corresponds to one of the reasons why you go to college.

Does not correspond at all		Corresponds a little		Corresponds moderately		Corresponds a lot		Corresponds exactly
1	2	3	4	5	6	7		

***WHY DO YOU GO TO COLLEGE?* (MOTIVATION)**

1. Because without a degree, I would not find a high-paying job later on.	1	2	3	4	5	6	7
2. Because I experience pleasure and satisfaction while learning new things.	1	2	3	4	5	6	7
3. Because I think that a college education will help me better prepare for the career I have chosen.	1	2	3	4	5	6	7
4. For the intense feelings I experience when I am communicating my own ideas to others.	1	2	3	4	5	6	7
5. Honestly, I don't know; I really feel that I am wasting my time in college.	1	2	3	4	5	6	7
6. For the pleasure I experience while surpassing myself in my studies.	1	2	3	4	5	6	7

Figure 16 Academic Motivation Scale (partial)[19]

The 7 sub-scales are:

1. Intrinsic Motivation - to know
2. Intrinsic Motivation - to accomplish things
3. Intrinsic Motivation - to experience stimulation
4. Extrinsic Motivation - External
5. Extrinsic Motivation - Introjected
6. Extrinsic Motivation - Identified Regulation
7. Amotivation

[19] The full AMS is in the Appendices

The key for decoding the 28 statements is reproduced as Figure 17, below.

KEY FOR AMS (Academic Motivation Scale)

# 2, 9, 16, 23	Intrinsic motivation - to know
# 6, 13, 20, 27	Intrinsic motivation - toward accomplishment
# 4, 11, 18, 25	Intrinsic motivation - to experience stimulation
# 3, 10, 17, 24	Extrinsic motivation - identified
# 7, 14, 21, 28	Extrinsic motivation - introjected
# 1, 8, 15, 22	Extrinsic motivation - external regulation
# 5, 12, 19, 26	Amotivation

Figure 17 Key for the AMS[20]

To present this information in this thesis, spider charts were used. A spider chart, also called radar or polar chart, uses a two-dimensional graph to display a multi-dimensional data structure, where the factors are represented as radii with a common beginning and equal length, along which the data are plotted. Points close to the centre *usually* indicate low (or negative) value, while points near the edge indicate a high (or positive) value (Atanassova 2010). Motivation and Engagement are separate but not fully independent. A student could be motivated in general but differ in their engagement levels with specific tasks. A score representing total motivation would be 100% for every category (except 0% for Amotivation).

Figure 18, see below, represents a 'perfectly motivated' individual.

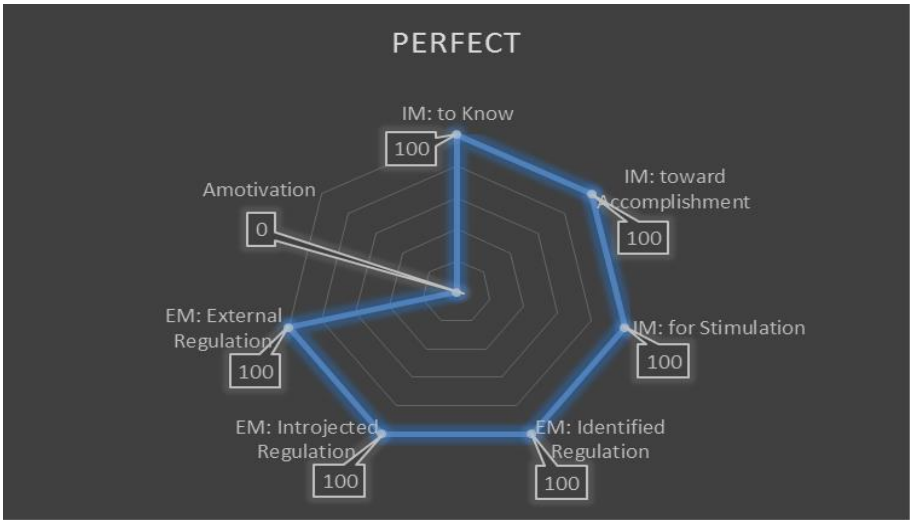


Figure 18 A Perfect AMS

[20] Found at https://tinyurl.com/amsenglish

It is reasonable to assume that Intrinsic Motivation is an unrealistic expectation for an instructor to have regarding their students, at least in the pure sense of all these students would continue to fully participate if there was no reward (other than the joy of learning) and no negative consequences if they quit.

Research has shown that Autonomous Motivation predicts persistence and adherence and is advantageous for effective performance, especially on complex or heuristic tasks that involve deep information processing or creativity (Amabile 1979; Sheldon 1995; Hennessey 2000). So, a 100% AMS score in Intrinsic Motivation indicates the strong (self-declared) presence of an overtly positive attribute. Extrinsic Motivation is less straightforward. The psychological constructs of Intrinsic & Extrinsic Motivation are not independent of each other in application. The literature indicates that Intrinsic and Extrinsic Motivation affect one another in a predictable, quantitative fashion. Deci et al.'s meta-analysis of 128 studies confirmed that extrinsic rewards decrease Intrinsic Motivation (1999). The study demonstrated that rewards were interpreted by recipients as controllers of their behaviour. When extrinsic rewards were given for an intrinsically interesting activity, this directly undermined their intrinsic motivation.

Engagement or application to a specific subject or activity is a key contributor of learning and academic success and a growing body of research has linked student engagement to higher grades and achievement in test scores, and school completion rates (Fredricks *et al.* 2004; Wang *et al.* 2016), and this is discussed in section 2.11.

2.11 Pedagogic Engagement Theory: Qualitative Theories of Engagement

Engagement refers to a student's active involvement and participation in school-based activities. Engagement entails students' reactions to, and interactions with, the learning material as it is embedded in the physical, instructional, and social environment, and has been studied actively for decades (Reeve *et al.* 2004; Appleton *et al.* 2008; Fredricks and McColskey 2012). Within the theoretical framework of SDL, a teacher's motivating influence is understood in terms of autonomy support vs. control; the student's motivation is understood in terms of engagement vs. disengagement (Deci and Ryan 1985; Deci *et al.* 1991; Deci and Ryan 2000; Reeve *et al.* 2004; Skinner *et al.* 2009; Jang *et al.* 2016). Once an educational system creates an educational program, then measuring its success on an individual level requires an analysis of the following

factors of engagement: Behavioural, Emotional, Cognitive, and Agentic. These dimensions of student engagement (Behavioural; Emotional; Cognitive) have been tested and empirically validated (Jimerson *et al.* 2003; Fredricks *et al.* 2004), with Agentic Engagement being a more recent addition (Veiga 2016).

The definitions are as follows (Reeve and Tseng 2011):

1. **Behavioural Engagement:** This is the participation, effort, on-task attention, persistence, positive conduct, and absence of disruptive conduct.
2. **Emotional Engagement:** This is the extent of positive and negative reactions to teacher and classmates, academics, and school, but also to a sense of belonging and identification with school and subject domains. It includes the presence of enthusiasm, absence of anger, anxiety, and boredom.
3. **Cognitive Engagement:** This is the level of investment in learning, being thoughtful, strategic, and willing to exert effort to understand complex ideas and mastering difficult tasks, and active self-regulation.
4. **Agentic Engagement:** This is the student's constructive contribution into the flow of the instruction they receive. What this new concept captures is the process in which students intentionally and somewhat proactively try to personalize and otherwise enrich both what is to be learned and the conditions and circumstances under which it is to be learned.

In addition, a socio-behavioural dimension should also be included, an examination of collaborative engagement in group-work (Fredricks *et al.* 2016). Järvelä et al.'s study focussed on how collaborative learning tasks were central for activating students' regulated learning, (e.g., time management or task understanding). This is not simply an equivalent of Motivation Theory's 'relatedness', but specific to how engagement is different when collaborating (Järvelä *et al.* 2016).

Any exploratory research can easily have objectives that are formed independently from a theoretical framework, but the chosen framework must exert a guiding influence on how exactly any exploration is to be conducted. In this case, forming both a conceptual and theoretical framework before designing the exploration provided clarity on how to achieve the objective of exploring design pedagogy with a 'designerly' equivalent of PBL: Solution-based Learning.

SDL provided the theoretical framework to make sense of the data gathered during the pedagogical exploration, but it also guided the creation of a simulated environment that allowed for the analysis of the facets of design thinking, solution-based learning, motivation, and engagement:

1. **Physical Puzzles**: They should have to be easily adjustable, not requiring any separate skill sets to attempt to solve them.
2. **Solution-based Learning**: Any design puzzles should somehow support multiple solutions to the design problem, as opposed to a single correct answer.
3. **Pedagogic Setting:** The puzzles should have to teach a specific design concept to the participants, in this case problem reframing.
4. **Competence:** The puzzles should allow for the participant to feel some level of competence, for them to gauge their abilities in a pedagogical environment.
5. **Relatedness:** The puzzles should allow for the participant to interact with others, to feel understood and cared for by others.
6. **Autonomy:** The puzzles should allow for the participant to be self-determined, to feel like they have some control.
7. **Behavioural Engagement:** The environment should allow for the examination of effort, on-task attention, and persistence.
8. **Cognitive Engagement:** The environment should allow for the examination of their investment in learning, their willingness to exert effort to understand complex ideas and master difficult tasks, and their active self-regulation.
9. **Emotional Engagement:** The environment should allow for the examination of enthusiasm, and the absence of anger, anxiety, & boredom.
10. **Agentic Engagement:** The environment should allow for the examination of a student's contribution into the flow of the instruction they receive, as they proactively try to personalize the event.

The pedagogic environment must fulfil those objectives, to follow the 'Self-process Model', (see Figure 19 below).

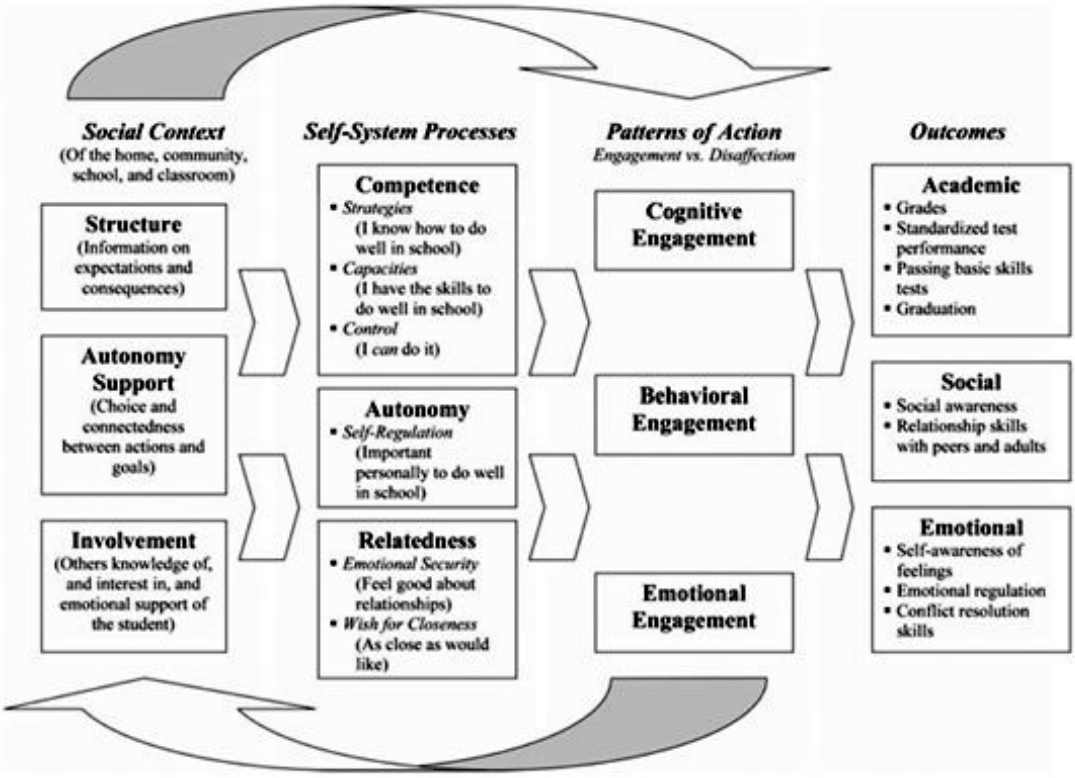


Figure 19 The Self-process Model; applied to Educational Settings[21]

The research environment and the methodologies employed to explore tacit problem reframing with Interaction Design students are discussed in the next chapter.

[21] Appleton, J.J., Christenson, S.L. and Furlong, M.J. (2008) 'Student engagement with school: Critical conceptual and methodological issues of the construct', *Psychology in the Schools*, 45(5), 369-386.

3 Methodology

3.1 Introduction

This research is an exploration of how Interaction Design students' understanding of the concept of 'problem reframing' could be tacitly developed by their attempting to solve tangible design puzzles.

For any defensible research claims, a Conceptual Framework must form a solid foundation for research endeavours. But any data produced needs to be analysed. A Theoretical Framework is required to make sense of that data, applied within a rigorous methodology. Educational practices cannot be understood except within the theoretical framework that makes them intelligible as practices and policies (Peshkin 1985; Pring 2004). The theoretical framework's influence on the research design decisions is discussed next (section 3.2).

This methodology is 'mixed method', meaning research that adopts a strategy of employing more than one type of research method. In this case, a mix of quantitative and qualitative methods (video analysis, surveys, and interviews). These methods are discussed in detail in sections 3.8-3.14.

3.2 The Theoretical Framework & the Pedagogic Environment

To apply self-determination theory in an educational context, an institution should provide an environment that supports the development of Competence, Relatedness, and Autonomy (Silva *et al.* 2014).

So, the design of this pedagogic research environment must focus on:

1. Testing the participant's competence in a pedagogical environment.
2. Examining how relatedness affects motivation.
3. Allowing opportunities for autonomous decision-making.

To examine 'competence', the puzzles would have to allow to gauge their individual abilities in a pedagogical environment, an opportunity for them to become unreasonable in their behaviour (Hummels and Frens 2008).

Advocates of ‘Cognitive Evaluation Theory’ argue that feedback that induces feelings of competence can enhance intrinsic motivation for that action (Deci and Ryan 1985). This exploration would be presented to participants as a personal challenge. Pre-testing (discussed in section 3.6) was carried to discern how solving all the puzzles in the limited time frame could be made challenging but not impossible.

To examine ‘relatedness’, participants were offered the choice to come on their own or bring a partner, (but only if that partner were also a design student). The researcher participated as Facilitator (instead of leaving the room), but never giving any guidance regarding strategy, only clarification and encouragement as needed (Järvelä *et al.* 2016). This behaviour was in accord with the distinction between Inquiry-based Learning and Problem-based Learning. In Inquiry-based Learning, the tutor plays an active role by providing information in a timely fashion. In Problem-based Learning, no actionable information should be given to the problem-solvers, but an active role is nonetheless fulfilled (Savery 2015).

To examine ‘autonomy’, genuine opportunities for behaving with a full sense of volition and choice would be presented (Ryan and Deci 2000). That all participants were volunteers meant that a general sense of choice was ubiquitous, but the environment was created with many other opportunities for personal choice during the activity itself.

Furthermore, SDL is a foundational element of Pedagogic Engagement theory. To examine engagement theory, the design of the exploration provided opportunity to examine the four elements of engagement: Behavioural, Cognitive, Emotional, and Agentic (Reeve and Tseng 2011; Veiga 2016).

1. Behavioural Engagement: The environment would have to allow for the examination of effort, on-task attention, and persistence (Jimerson *et al.* 2003).
2. Cognitive Engagement: The environment would have to allow for the examination of their investment in learning, their willingness to exert effort to understand complex ideas and master difficult tasks, and their active self-regulation (Fredricks *et al.* 2004).
3. Emotional Engagement: The environment would have to allow for the examination of enthusiasm, and the absence of anger, anxiety, & boredom (Veiga 2016).

4. Agentic Engagement: The environment would have to allow for the examination of a student's contribution into the flow of the instruction they receive, as they proactively try to personalize the event (Reeve and Tseng 2011).

While these are separate intellectual constructs, it is not possible to present a series of puzzles that address each facet exclusively. This is because they are descriptors of different aspects of the same process, that of being engaged (Appleton, J.J., *et al.* 2008). The puzzles were designed so that all four constructs of engagement could naturally ebb, flow, and interact with each other while the participant was working on the puzzles. These processes would be delineated after the fact, during data analysis.

While Behavioural, Cognitive, Emotional Engagement are all categories of attitudes and emotions, Agentic Engagement can be dealt with separately, to an extent. Even so, introducing agency into any educational program is fraught with difficulties. Syllabuses are created by those who know, who understand the material fully. Direct input from those that are learning, who know less, seems counter-productive. While a choice from elective modules presents an opportunity for learner agency, it is agency to a very limited degree. Presenting opportunities for learners to adjust how their instruction is presented, to allow learners to "contribute into the flow of the instruction they receive" by choosing what levels of assistance they require, is not a trivial undertaking (Reeve and Tseng 2011, p.2).

The opportunities for agency in this setting were as follows:

1. The participants would be free to start with whichever puzzle they wanted.
2. They would not have to finish any puzzle to 'qualify' to move on to another.
3. They could leave a puzzle and try a different one at will and return if/when they wanted.
4. There would be clues, easily accessible but placed in small opaque drawers so that their contents would be obscured until opened. The participants would be told that accessing the clues should increase their chances of successfully solving the puzzles, but would reduce the challenge element, directly affecting the balance between what they were learning by discovery and learning by instruction.

The clues were conceived as follows, see Table 7 below:

Clue 1	Stating the obvious, in case the participant was completely off-track.
Clue 2	A strong push towards the solution, but it would only be understood as such if the participants were almost there.
Clue 3	Almost giving the game away, but not fully.

Table 7 Clues

The clues were created for each puzzle to provide scaffolding, and decisions were made that sometimes a written clue was best, sometimes a graphic, and sometimes a physical item, see Table 8 below.

Type of Clue	Dalén Lamp	Slow Elevator	Smuggling Scarecrow
Written	1	2	2
Graphic	0	0	1
Physical	2	1	0

Table 8 Clue Breakdown

In addition, this pedagogical exploration would be a timed event, for two reasons. The first reason was that this research had the objective of producing actionable information (Collins *et al.* 2004). Insights from this research could have future application as a pedagogic element of an Interaction Design course, with structured classes and modules that have scheduled time limits. This exploration would be a structured process that could adhere to an appropriate schedule. The second reason was because research suggests that explicit time pressure stimulates creativity (Schmitt *et al.* 2012). The time pressure would also add to the gamification elements, to add some frisson. According to McFadzean (1998), research at the University of Michigan showed that laughter causes the release of endorphins, which in turn provide a burst of energy and an impetus to creativity. Creating a pedagogic setting that is both engaging and teaches something

of value is non-trivial, as students often misunderstand teachers' goals (mastery goals) and direct their actions towards work goals (e.g., finishing the task as soon as possible) and evaluation-oriented goals (e.g., avoiding poor grades) (Savery and Duffy 1995; Lemos 1999).

3.3 Research Design Decisions

To adhere to the Self-determined Learning theoretical framework, these puzzles would have to allow participants the opportunity to gauge their own competence, to be able to interact with a peer (or with the Facilitator) in the way they want to, (including not interacting at all), and to self-regulate; to interact with the puzzles in the way they wanted to, to learn the way they wanted to learn (Boekaerts 2016). To explore from a Constructionist perspective, the puzzles would be tangible, allowing for easy deconstruction and reconstruction (Ackermann 2001).

Preliminary testing by the researcher, regarding the best choice of construction materials, began with LEGO™. It proved easy to build with but was too inflexible regarding the type of builds required. Preliminary testing with Meccano™ was satisfactory, but it required a degree of mechanical skill and practice to build efficiently when following a set of instructions, and even more so when trying to create with it. For this research, the learning curve had to be flattened as much as possible, so that it would be inconsequential. Participants had to be allowed to focus on creating a solution to the puzzle, and not get distracted by having to learn how to build it. Preliminary testing with K'Nex™ was immediately successful. This popular building toy combines a Lego-like click together system with Meccano-like structural capabilities, with motors to power moving parts, see Figure 20, below.

Figure 20 A selection of K'Nex sets

The selected building materials would allow for the construction of designerly puzzles, with the possibility of multiple acceptable solutions, but only acceptable as solutions if they meet the original specifications of the design brief (Vincent *et al.* 2002).

A standard method for introducing design concepts is to present examples in lecture of successful applications of 'Design Thinking' or 'Problem Reframing'. These spectacular examples of insight are illustrative but is the medical training equivalent of explaining how a vaccine was discovered, with no opportunity for the students to mimic any of their future professional practice.

Instead of students listening passively in lecture to a historical example, students could enact that specific example, creating the solution themselves by thinking with their hands, by active, tacit learning (Gagnon and Collay 2005). This could be achieved by their attempting to solve an insight puzzle that replicates (as far as possible) the problem faced by that historical designer. This would facilitate their learning outcome of gaining tacit knowledge by becoming *unreasonable* with practice (Perkins 2001).

Research into educational games concludes that if a game is not engaging emotionally, then it loses its power to engage educationally (Hanghøj (2011). If these puzzles were to engage educationally, they would have to engage both emotionally and cognitively. The puzzles were never meant to be just playtime but were designed with an understanding of the pedagogic distinction between *Learning to Do* and *Learning by Doing* (Özkar 2007). To illustrate *Learning to Do*: if someone wants to become a competitive swimmer, they must get in the pool and practice swimming. While they should also eat well and go to the gym, those activities are explicitly to facilitate improvement in swim performance, supporting what the individual is *learning to do*, learning to swim competitively.

On the other hand, *Learning by Doing* is when you learn something indirectly but deliberately, with sketching being an excellent example of the mental process of discovery in design. You sketch physically, but you are drawing as a process of discovery, as a separate cognitive process (Cross 1999b). These puzzles are intended to be analogous to sketching in the sense that these puzzles are intended to be examples of *learning by doing* where students would be solving a puzzle, but that activity would actually be the mechanism by which they could gain an understanding of some elusive design concept (Buxton 2010), which in this case is problem reframing.

When lecturers present examples of famous problem solvers, the explanation of problem reframing is a key instructional element, as it is an important ability for every Interaction Designer to understand and develop (Schön 1983; Vallée-Tourangeau *et al.* 2015). The physical design puzzles used in this exploration all require reframing to solve, the defining characteristic of an insight puzzle (Gilhooly and Murphy 2005; Webb *et al.* 2016). So, reframing is the focal point of the puzzles. As the puzzles are representations of famous design problems, then the successfully design of these puzzles would be the transferring of a historical example's 'reframing event'.

3.4 Historical Ill-defined Problems

Ill-defined problems are defined by having insufficient information to allow for incremental progress and require a restructuring, a reframing in how the problem is approached (DeYoung *et al.* 2008). This reframing requires the designer to be 'ill-behaved'. Novices and expert designers behave differently, with experts leveraging their superior depth of knowledge and experience to reach conclusions faster, jumping to the abductive reasoning stage with more readiness than novices, who spend more time carefully gathering all available information. Experts quickly focus on solution-generation; novices keep their focus on problem-analysis for longer (Cross 2004; Kruger and Cross 2006). Every designer's comprehension, their chunking of the problem, is informed by their previous knowledge and experience. So, any ability to reframe the problem, to perform chunk decomposition, is also dependant on individual knowledge and experience (Weller *et al.* 2011).

Therefore, creativity does not spring from a vacuum. This researcher disputes, in the strongest possible terms, that all examples of creative design are acts of divergent thinking alone, that someone is either creative or that they are not, (and if not, they will never become a creative individual). Acts of creative thinking are a complex mixture of divergent and convergent thinking, of experience and knowledge, of logical inference, combining abductive, inductive, and deductive logic with everything they know and everything they understand (Ohlsson 2011). It is also relational, dependant on what and whom you are interacting with (Weisberg 2015).

Undergraduate students are limited in knowledge and skills, especially in comparison with those professionals who were so insightful that their work is still discussed as

examples. It would be unreasonable to expect these design students to be capable of reproducing these spectacular historical examples of insightful problem reframing. To enable every participant to have some successes, an amount of scaffolding, of funnelling them in a purposeful direction, would be required (Vygotsky 1987).

Participants would be given an initial problem statement that quickly provided them with the impasse (Scheerer 1963). They would know that the puzzles were representations of historical design solutions, (so a solution was obviously possible), but they would not know which historical examples. They would also know that there were clues available. Tomas Dorta once described how the structure of software interfaces, such as CAD or Photoshop, can restrict ideation and just encourage representation (2008). However, this usually negative effect of a narrowing of the perceptual space was precisely what this researcher wanted to achieve. The objective was never to teach participants how to build well with K'Nex. It was to explore a novel teaching method, analogous to sketching where design students would learn by doing, where students learn how to reframe, by 'constraint relaxation', and practice creating solutions that would fit that new frame (Chu and MacGregor 2011).

According to Dorst, design problems can be paradoxical in their initial context and that design thinking is the process of working around this paradox, rather than confronting it. The problem must be appraised and reframed before it can be approached (2015). The problem-solver's solution strategy for an ill-defined problem must be determined by three stages (Cross 2001; Webb *et al.* 2016):

1. The initial representation leads to an impasse in which progress halts.
2. To break the impasse, the problem representation must be reframed, restructured, to allow fresh directions of search.
3. A restructuring that leads to a rapid and complete understanding of how the solution can be reached is often referred to as an insight.

After discussions with other design instructors, appropriate historical design solutions, considered to be excellent examples of problem reframing, were selected, and then examined. Their consideration for this pedagogic exploration was based on an analysis that delineated them into the following categories:

1. Initial Problem
2. Impasse

3. Reframing
4. Insight

These examples are presented in the following pages, in the Tables 9-23.

Problem 1: Da Vinci's Aerial Screw	
Initial Problem	How to imitate birds, to create a way for humans to fly!
Impasse	The wings would have to be huge! Decreasing their size decreases their capability.
Reframing	Do we have to fly just like birds? The sail on a ship could be like a wood screw…
Insight	A propeller amounts to an air screw, holding on to air much as a wood screw holds on to wood.

Table 9 Da Vinci's Aerial Screw

Problem 2: Gutenberg's Printing Press	
Initial Problem	How to create a machine for the mass production of books!
Impasse	How can I solve the problem of printing pages, without rubbing them by hand against the inked print?
Reframing	Gutenberg: "I took part in a wine harvest. I watched the wine flowing, and going back from the effect to the cause, I studied the power of this press, which nothing can resist."
Insight	Applying a winepress-type mechanism to a piece of paper lying on an inked page constructed out of moveable letters would result in the page being printed on the paper.

Table 10 Gutenberg's Printing Press

Problem 3: Wilkin's Radar	
Initial Problem	Use radio waves to heat eight pints of water from a temp of 98° to a temp of 105° at 5km and a height of 1km!
Impasse	Radio waves have neither the power nor the range to do so.
Reframing	Instead of using radio waves to interfere with planes, focus on how planes interfere with radio waves.
Insight	The request was to create a "death ray". He realised that the early detection of German planes would also be very useful.

Table 11 Wilkin's Radar

Problem 4: Mendeleev's Periodic Table	
Initial Problem	Create a Periodic Table of naturally occurring elements!
Impasse	An incomplete knowledge of elements.
Reframing	Is there really a need to wait until after the elements are found, and only then testing their attributes?
Insight	He filled in the gaps by reasoning on his understanding of the elements that were known.

Table 12 Mendeleev's Periodic Table

Problem 5: Bohr's Atomic Model[22]	
Initial Problem	Contemporary understanding of the atomic model was based on some evidence but was obviously flawed!
Impasse	This current understanding predicted that all atoms are critically unstable at all times.
Reframing	The electrons must somehow not be losing energy!
Insight	He suggested that electrons only gain and lose energy by jumping from one allowed orbit to another.

Table 13 Bohr's Atomic Model

Problem 6: Wallenberg's Tetra Pak	
Initial Problem	To produce a viable packaging for milk that was cheap enough to compete with the current system of reusable glass bottles!
Impasse	The research lab had tried and failed with several different solutions.
Reframing	Wallenberg realised the material did not have to be as inherently strong as it was in existing packaging if the strength came from somewhere else.
Insight	He used one single sheet of paper rolled into a cylinder and folded from two different sides, creating a mathematical tetrahedron.

Table 14 Wallenberg's Tetra Pak

Problem 7: Watson and Crick's (and Franklin's) DNA	
Initial Problem	Create a model of Human DNA!
Impasse	They could see (from X-ray diffraction patterns) that it had a double-helix structure, but their model was self-contradictory.
Reframing	New knowledge corrected an error in basic understanding. The configuration for the rings of carbon, nitrogen, hydrogen, and oxygen (the elements of all four bases) in thymine and guanine in most chemistry textbooks had been incorrect but was corrected during this research period.
Insight	While shifting around the cardboard cut-outs of the accurate molecules on his office table, Watson realized that if A always paired with T, and likewise C with G, the pairs could be neatly fitted between the two helical sugar-phosphate backbones of DNA, the outside rails of the ladder.

Table 15 Watson and Crick's DNA

[22] I acknowledge the Bohr Model was replaced by Schrodinger's Model.

Problem 8: Edison's Light Bulb	
Initial Problem	Make a cheap, mass-producible light bulb!
Impasse	Carbon would have been perfect, except that it burned too easily (quickly) with oxygen. Platinum was then used and was excellent, but expensive.
Reframing	Vacuum technology was improved. With no oxygen present, a return to carbon was made.
Insight	Edison's sudden change from platinum to carbon.

Table 16 Edison's Light Bulb

Problem 9: Sundbäck's Zipper	
Initial Problem	Replace the 'hooks and eyes' fastening system!
Impasse	Initial versions of the zipper tended to easily pull apart.
Reframing	The basic design worked but was simply not strong enough.
Insight	Sundbäck increased the number of fastening elements per inch.

Table 17 Sundbäck's Zipper

Problem 10: Nobel's Dynamite	
Initial Problem	Nitro-glycerine was useful, but volatile and dangerous!
Impasse	Chemical knowledge was not as extensive as it is now.
Reframing	Nitro explodes when shook, so create a chemical "cushion"!
Insight	Mixing it with a silica called 'diatomaceous earth' created this cushion/stability.

Table 18 Nobel's Dynamite

Problem 11: Fuller's Tensegrity & Geodesic Domes	
Initial Problem	Create a more efficient method for creating structures!
Impasse	Compression structures (bricks-on-bricks) were logical, but was there a more efficient way?
Reframing	Gravity can be replaced by tensional integrity.
Insight	Tensegrity is a principle based on the use of isolated components in compression inside a net of continuous tension, in such a way that the compressed members (usually bars or struts) do not touch each other and the pre-stressed tensioned members (usually cables or tendons) delineate the system spatially.

Table 19 Fuller's Geodesic Domes

Problem 12: Engelbart's Mouse & GUI	
Initial Problem	A GUI was better than wading through screens of text.
Impasse	But, how to navigate through a GUI without typing?
Reframing	Ambiguity (for computers) is a bad thing.
Insight	Point-and-click resolved any ambiguity.

Table 20 Engelbart's Mouse & GUI

Problem 13: Berners-Lee's WWW	
Initial Problem	It was difficult for non-experts to navigate the Internet.
Impasse	How could the user dictate how they take in information?
Reframing	Could the Internet become a non-linear experience?
Insight	Apply hypertext to the Internet to create the WWW.

Table 21 Berners-Lee's World-wide Web

Problem 14: 4 Pens & 17 animals	
Initial Problem	Place all 17 animals in the 4 pens, where there is an even number of animals in each.
Impasse	Mathematically impossible (without using Sets), but that is not immediately obvious to non-mathematicians.
Reframing	Realising that pens can overlap.
Insight	Create Sets.

Table 22 4 Pens & 17 animals

Problem 15: Maier's Pendulum Problem	
Initial Problem	Two cords are hanging from the ceiling. Please tie them together.
Impasse	The two cords were far enough apart so that if you held one cord, you could not reach the other, even if the supplied pliers are used.
Reframing	The pliers can be used as a weight, instead of their usual use, to help one of the cords swing.
Insight	By swinging one cord, then grabbing the stationary one, the swinging cord could be caught when it swung back.

Table 23 Maier's Pendulum Problem

3.5 Pre-Testing the Puzzles

Da Vinci's example did lend itself to a physical puzzle format, but during the puzzle's initial design stage, the researcher realised that the solution would become obvious if a participant remembered a helicopter, rather than the puzzle requiring them to be creative. It proved difficult to reimagine Gutenberg's Printing Press in the required format, even though his use of a novel analogy was similar to Da Vinci's. On reflection, Watson, Crick & Franklin's discovery of the DNA Helix and Edison's Light Bulb both shared the analytical method of 'restarting after new information is discovered', and so were representative examples of purely deductive logic, rather than abductive logic. While all these scientists employed a variety of analytical methods that students could learn from, all those examples either resisted an appropriate physical representation suitable for this exploration or obviously relied too heavily on the student's memory (their reproductive thinking).

Eventually, five insight puzzles were developed, built and pre-tested. Three testers were recruited to test the exploratory designs, see Table 24, below.

ID	Knowledge Base	Age Range
Tester1	Interaction Designer/Researcher	20s
Tester2	Interaction Designer	20s
Tester3	Expert in Constructivism/Constructionism/WeDo Lego Instructional System	20s

Table 24 Pre-testing the puzzles

Firstly, versions of two traditional insight puzzles were built to explore how participants might interact with tangible puzzles. Puzzle 1 was the '9-dot Problem', discussed earlier on page 36, see Table 25 below.

Problem 17: The 9-dot Problem	
Initial Problem	The goal of the puzzle is to link all 9 dots using four straight lines or fewer, without lifting the pen and without tracing the same line more than once.
Impasse	The assumed constraint of having to stay inside the box shape.
Reframing	Realising you do not have to stay within that box shape.
Insight	Easy to draw the solution, after relaxing that imagined constraint of staying inside the box.

Table 25 The 9-dot Problem

This K'Nex puzzle required winding a cord around the pegs, rather than having a pen to draw with. On the left of Figure 21, see below, is what the pre-testers were given. A solution is on the right, displaying one way of extending the puzzle.

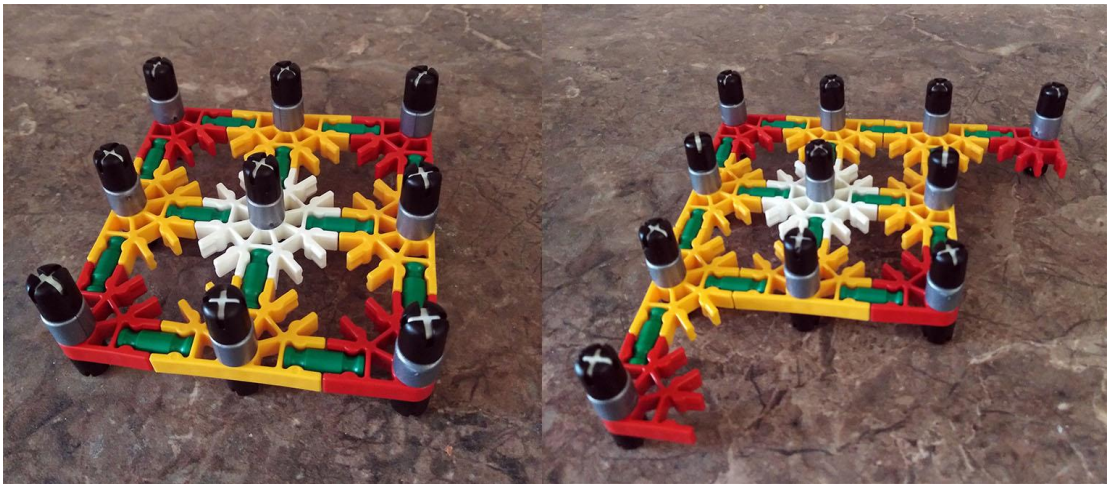


Figure 21 K'Nex 9-dot puzzle

However, none of the testers (Testers 1, 2 & 3) were able to make any progress inside 15 minutes and by then were clearly becoming irritated. Their 'think-aloud' commentary revealed that they had absolutely no idea what to do, with none of them even picking up a new K'Nex piece to explore possible solutions. The assumed constraint of having to stay inside the box shape seemed to be reinforced by the physicality of the puzzle, rather than being diminished (Chein *et al.* 2010). When asked what clues would have been helpful, they all struggled to articulate anything, except the need for an explicit drawing of the solution. This puzzle was eliminated from consideration because it seemed too obtuse in this form, too difficult.

A version of the 8-coin problem was developed, see Table 26 below.

Problem 17: The 8-coin Problem	
Initial Problem	The 8-coin problem, where the goal is to transform a given arrangement of 8 coins, so that each coin touches exactly 3 others in a specified number of moves.
Impasse	A 2D solution is not possible.
Reframing	The coins have to be placed on a flat surface, but do they all have to be placed on the same surface?
Insight	Gravity demands a flat surface, but the coins could be placed on each other too, in 3 dimensions!

Table 26 The 8-coin Problem

Conversely, two of the testers (Testers 1 & 2) solved this inside three minutes, seemingly without needing any serious consideration of it as an insight puzzle. After picking up the discs (poker chips) and playing with them in their hands, their brief 'think-aloud' commentary consisted of exclaiming, "Oh, yeah, you can just put them on each other". A 3D solution seemed obvious because of the physicality of the discs, how they stacked in their hands quite naturally, see Figure 22, below.

Figure 22 Poker Chips

When asked what clues would have been helpful, all three said there was no real need. This puzzle was eliminated from consideration because it appeared too easy, at least in this physical form, with these discs being much bigger (and lighter) than coins.

It was interesting to observe at this early stage that the materials used in creating these two physical puzzles seemed to have an obvious impact on reasoning ability. Donald Norman called this the 'representational effect', where different representations of a common formal structure can cause different cognitive behaviours. He explored this effect with different representations of the Tower of Hanoi puzzle (p.35). As an example of the representational effect, the multiplication of Arabic numerals is more efficient than Roman numerals (24 x 9 is easier than XXIV x IX), even though both systems represent numbers (Zhang and Norman 1994).

So, Tester 3 was asked to solve the 8-coin puzzle with 8 coins (8x 1 Euro coins). The coins were placed on the table, just like the poker chips, but were not picked up in the same way (as a stack). Tester 3 played for two minutes without any obvious progress,

sliding the coins around each other. She was then switched to the discs by the researcher. She picked them up from the table and stacked them in her hand without thinking, then solved the puzzle inside two minutes, explaining that the discs “were lighter” and it was “easy to stack them”.

All three testers were invited to retry the 9-dot problem on paper. While none of them solved it within 15 minutes, they were not as obviously frustrated as they had been before. A 15-minute time limit for both puzzle try-outs was in place as the plan was to have the participating students try to solve all 3 puzzles in 45 minutes.

This preliminary data was not particularly influential in the designs of the puzzles that would eventually be used in the pedagogic exploration, as that was dictated by the nature of the puzzle itself and its ‘reframing event’. But it was noted that the materials themselves seemed to exert an influence. This could include the colours of the materials. The K’Nex is multi-coloured, with the colours being a mechanism for coding the different lengths of the pieces. For example, if a green piece is not long enough, then a longer white piece might do.

The historical examples of design thinking that eventually became the three physical problems used in this exploration were: The Dalén Light; The Williams F1 Suspension System; and The New York Elevator Problem, see Figure 23 below.

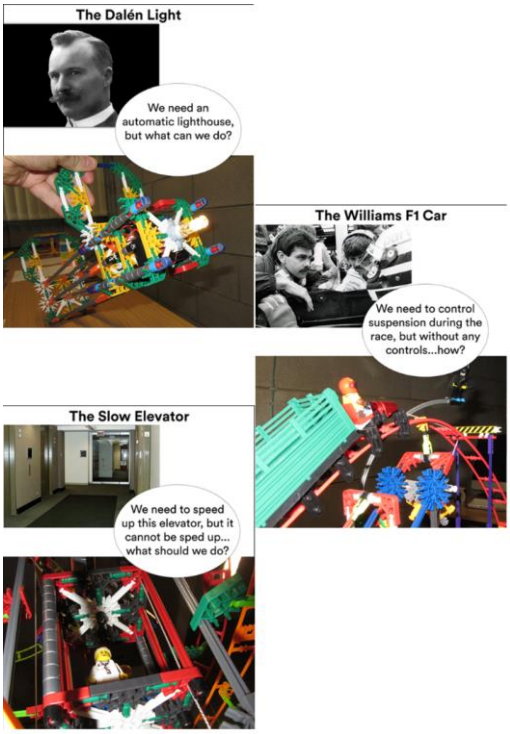


Figure 23 **The 3 Puzzles**

3.5.1 The Dalén Light

Historical Problem: Lighthouses have played an important part in maritime history (the Lighthouse of Alexandria was one of the Seven Wonders of the Ancient World). By the beginning of the 20th Century, there was a long history regarding the methods employed for creating a powerful light source. However, these varied methods relied on a person to turn the light on and off. An automated system would be most useful.

Historical Solution: Gustaf Dalén (1869-1937) was a Swedish industrialist. He is famous for inventing the AGA cooker, but he also won the Nobel Prize for Physics in 1912 for his Dalén Light, (Sun Valve), see Figure 24, to the right.

His Sun Valve became the flow control valve in lighthouses all across the world. It consisted of four rods made of identical materials, but with different coatings.

Figure 24 Gustaf Dalén's Sun Valve

The centre rod was blackened, and the other three were light-reflecting. During the night, all the rods were the same temperature and length. As sunlight fell onto all of the rods through a window and heated them up, the blackened rod absorbs more heat than the others and expanded, becoming slightly longer. This cut off the gas supply, switching off the lighthouse light. The gas flow was lit by a small, always-burning pilot light[23].

[23] Dalén , NG. "Aktiebolaget Gasaccumulator" Swedish Patent 25046 (1906)

Gustaf Dalén's 'design thinking' is discussed in Table 27, see below.

The Dalén Light	
Initial Problem	Make an automatic lighthouse lamp!
Impasse	There is no way of automatically having it turn on and off when needed.
Reframing	Can a natural force be leveraged to fulfil the objective? It must switch off during the day and switch on at night. So, the sun must be the key…
Insight	The sun's heat affects different things in different ways!

Table 27 The Dalén Light

The first operational version is seen in Figure 25, below.

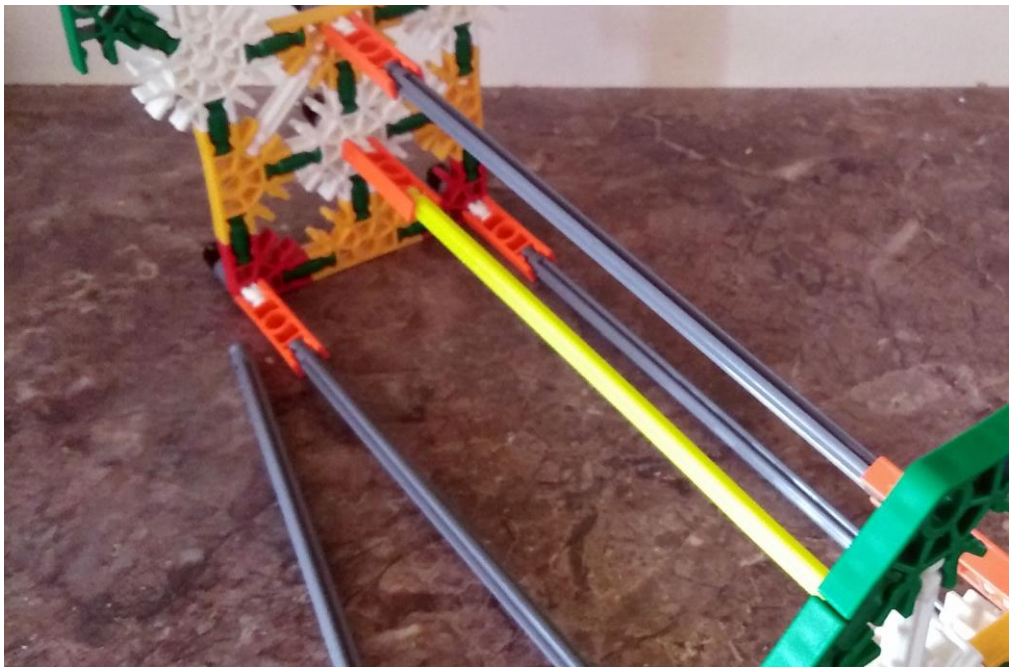


Figure 25 First Dalén Lamp

When designing a K'Nex version of the Sun Valve, it was reasonable to presume that undergraduate design students would not know of the Sun Valve. But, as this was the puzzle that was most literally related to its inspiration, it was made horizontal in structure to disguise any subliminal reference to a lighthouse. Lighthouses were not referred to until after their experience was over.

There had to be a judgement about how far away from the solution the starting position should be placed. This required some pre-testing to gauge what was reasonable. According to the pre-testers, after reflecting on their experience, the initial design (with

3 outer rods) had provided too much funnelling toward a solution. So, the redesigned puzzle now had 8 outer rods, primarily to obscure the path to a solution.

That version of the Dalén Lamp puzzle is seen below in Figure 26.

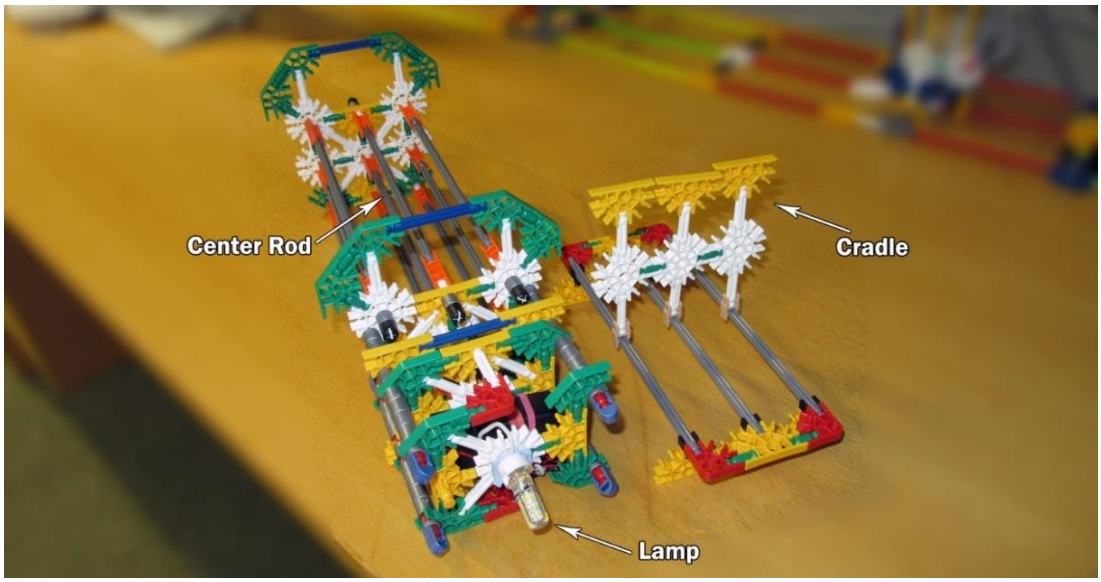


Figure 26 Initial Design: The Dalén Lamp

The Dalén Lamp and its cradle were subsequently rebuilt to be more substantial, even though it made no obvious difference to how any solution could be applied. This was because, during additional pre-testing, Tester 2 picked up the Lamp and immediately smashed it against the cradle, breaking both. When asked why she did that, she replied, "that's how I check everything".

The physical constraints of the K'Nex puzzle meant that any solution would have to become a part of that K'Nex structure. This was a deliberate strategy, to guide participants toward an appropriate solution (Dorta 2008). The student's first contact with each puzzle was always by reading the printed design brief or problem-statement. The Dalén Light's problem brief was placed face down on the table next to the puzzle.

When the participant was ready, they read the following[24], see Figure 27 below:

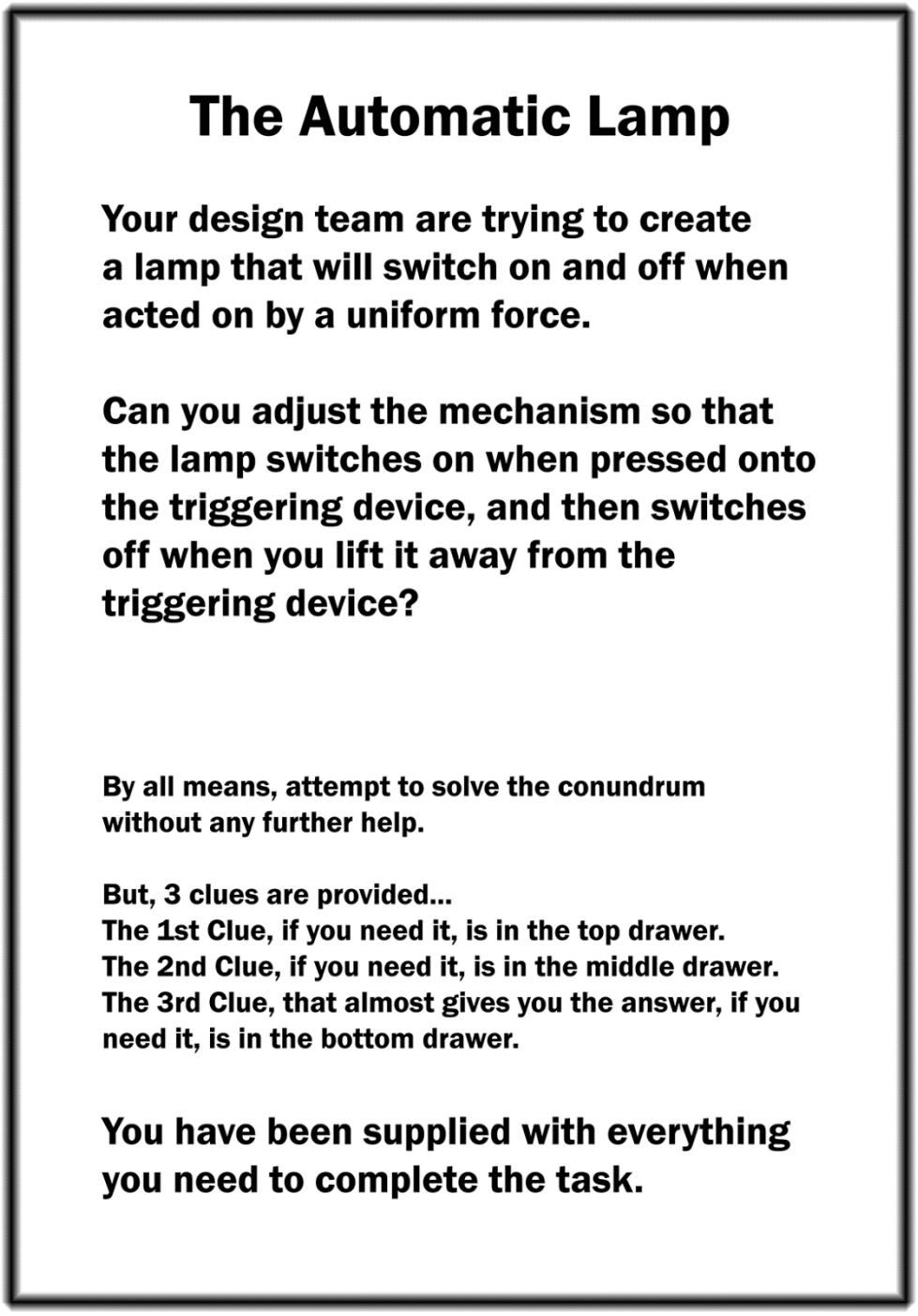


Figure 27 The Dalén Lamp: Problem Statement

[24] The Automatic Lamp will be referred to as The Dalén Lamp from now on.

The ‘design thinking’ behind this puzzle’s design is described in Table 28, see below.

The K’Nex Version of: The Dalén Light	
Initial Problem	The student must get the lamp to light up by pressing the entire mechanism against a cradle.
Impasse	The light remains switched off no matter how it is pressed on to the cradle.
Reframing	As the type of force applied cannot be altered, can things be changed so that a uniform force will affect parts of the mechanism in different ways?
Insight	The rigid central rod keeps the lamp switched off. A solution could be to exchange the central rigid rod with a flexible K’Nex rod (one of the items supplied with the craft materials) and to remove at least one of the other rods to provide access to that central rod.

Table 28 K'Nex version of The Dalén Lamp

The Dalén Lamp and cradle, see Figure 28 below, were rebuilt to be much more robust as a precaution (although no participants would turn out to be as heavy-handed as Tester 2). The cradle was stuck to the table (with Blu Tack™) but could be moved if a participant wished so, though this was not necessary. If participants started to do so, it would be suggested that such an action would be a waste of their time.

Figure 28 Final Design: The Dalén Lamp & Cradle

Note: A single structural change was made to the Dalén Lamp structure after the research had begun. This researcher acknowledges that changing an element and assuming the change makes no difference is dangerous, but it was necessary. Despite everyone being told explicitly, and repeatedly, that the battery compartment and LED itself should not be adjusted, several participants did exactly that. This meant the mechanism had to be quickly repaired during tests. For example, the battery compartment has a barely accessible off-switch, but if a determined participant really, really wanted to turn the battery off, they could just about reach it. This would mean that the Dalén Lamp could never come on regardless of any ingenious solutions. So, extra K'Nex pieces were added to surround the battery, so it was now inaccessible. This researcher wanted to have the freedom of speech to specifically say "nothing is glued down" to all participants, to encourage them to freely take things apart, (hence the sometimes-convoluted ways of securing elements of the puzzles in place).

As mentioned, the rigid central rod keeps the Dalén Lamp switched off. Working out how the switch works is simply a matter of applying Inductive Logic, a process accelerated by a background in any engineering discipline (especially in electronics), or simply being used to working with one's hands.

Clues would be easily accessible, (one at a time), but were fully obscured in their closed drawered container, until they were opened as in Figure 29, see below.

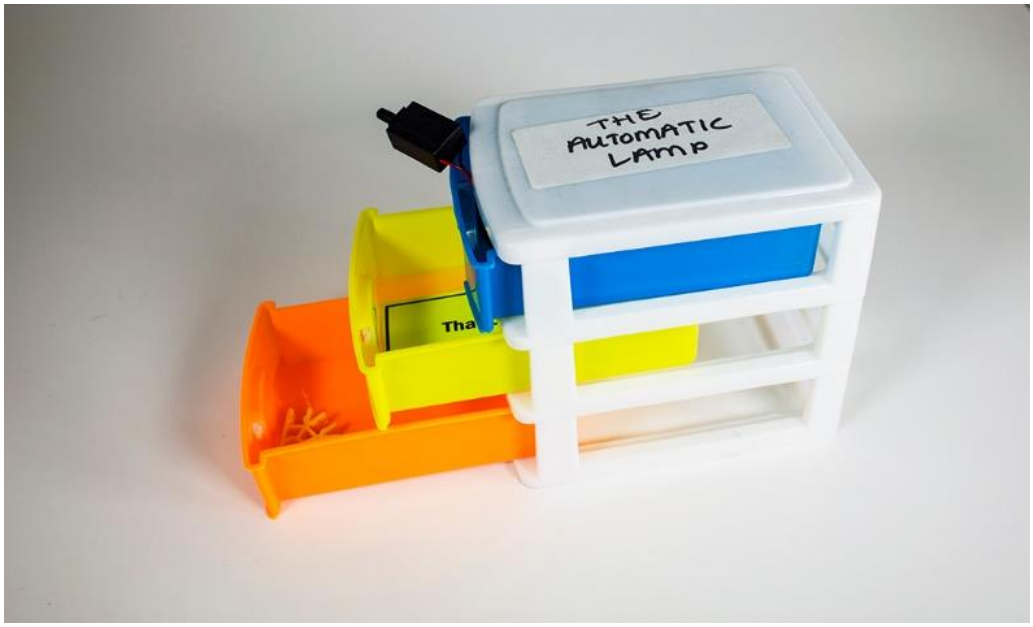


Figure 29 The Dalén Lamp clues

If a participant were struggling with the puzzle, then accessing the 1st clue would help (although they do not know exactly how ahead of time).

The 1st Clue reveals a duplicate of the switch, as seen below in Figure 30.

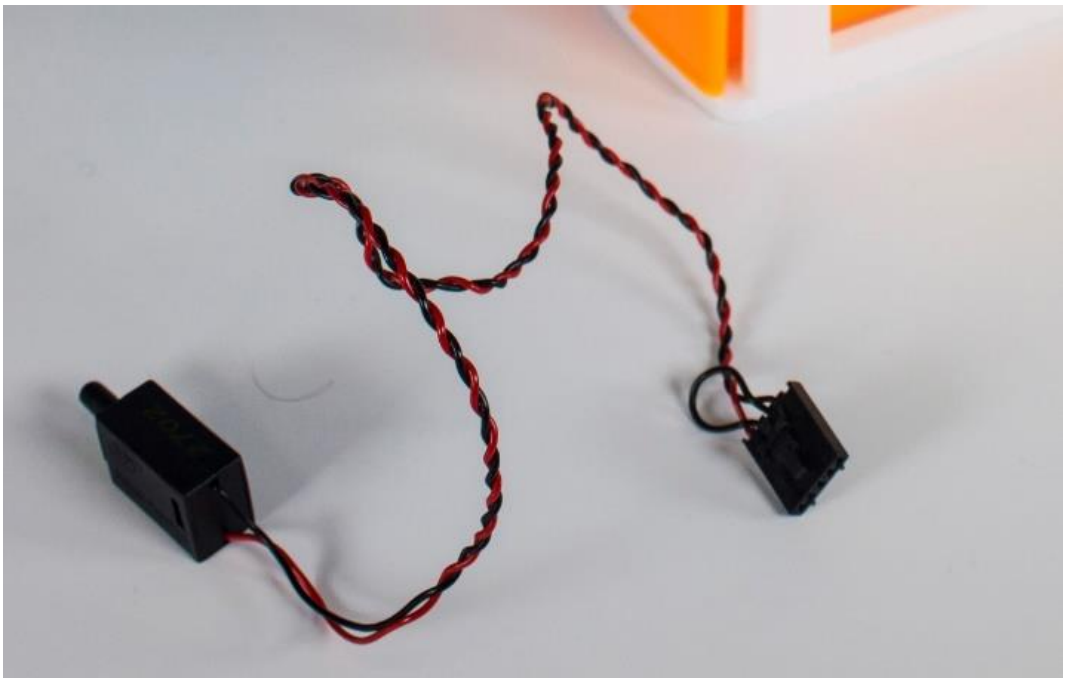


Figure 30 The Dalén Lamp: Clue 1

Note: In the 1st official test (with Participant 1), Clue 1 was a card that read, "Never let anything stand in your way!" Afterwards, this participant pointed out that their complete lack of electronics knowledge delayed their understanding of how the switch worked, making that puzzle much harder. Therefore, the researcher decided that an understanding of the switch itself would be a more useful clue and replaced the written clue with a duplicate of the switch for subsequent testing. The data from that 1st participant is still included in the overall findings because she would eventually prove to the best performer, completing all the puzzles in the shortest time. If she had seen the switch, (and been provided with an explanation of how it functioned), it is reasonable to presume that she would have finished even sooner. All 3 pre-testers had some electronics experience (the researcher and Tester 3 are quite expert), and this issue had not been picked up by any of the pre-testers or the researcher. When this clue was accessed, it demonstrated how the switch works. While all participants would have to apply this new knowledge, no participant had any problem performing this transfer.

Removing the centre rod releases the switch and the K'Nex Dalén Lamp switches on, as seen in Figure 31 below.

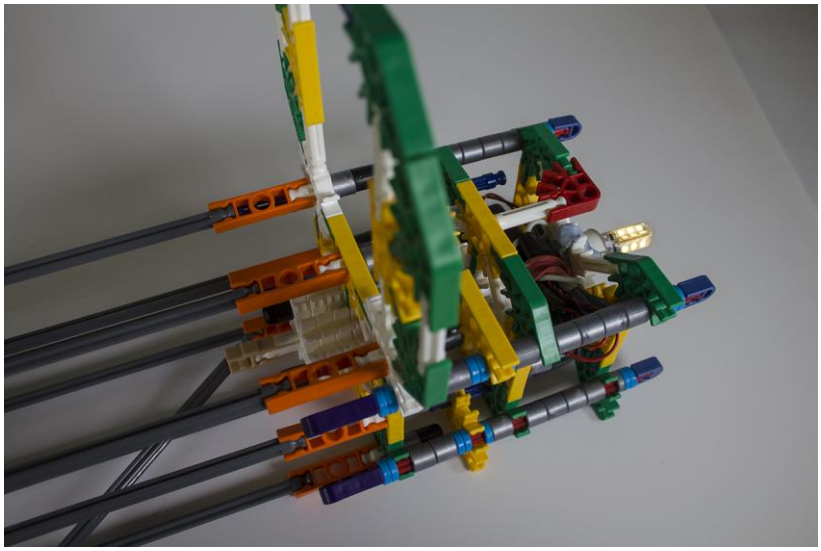


Figure 31 The Dalén Lamp: No Rod

However, this means that K'Nex Dalén Lamp is now permanently on. The design brief said that it must switch on when pressed onto the triggering device, but then switch back off when lifted away from the triggering device. The simplest solution is to exchange the central rigid K'Nex rod with a flexible K'Nex rod (supplied with the craft materials) and to remove at least one of the other rods so when the K'Nex Dalén Lamp is pressed down onto the cradle, the centre rod is bent and pulls the switch open, released by moderate pressure on the flexible rod, see Figure 32 below.

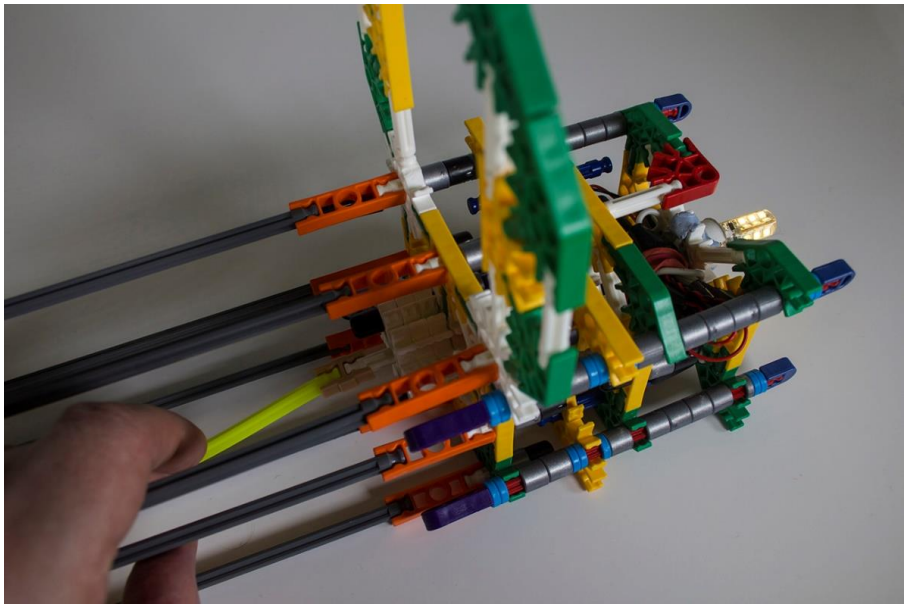


Figure 32 The Dalén Lamp: Pressure Release

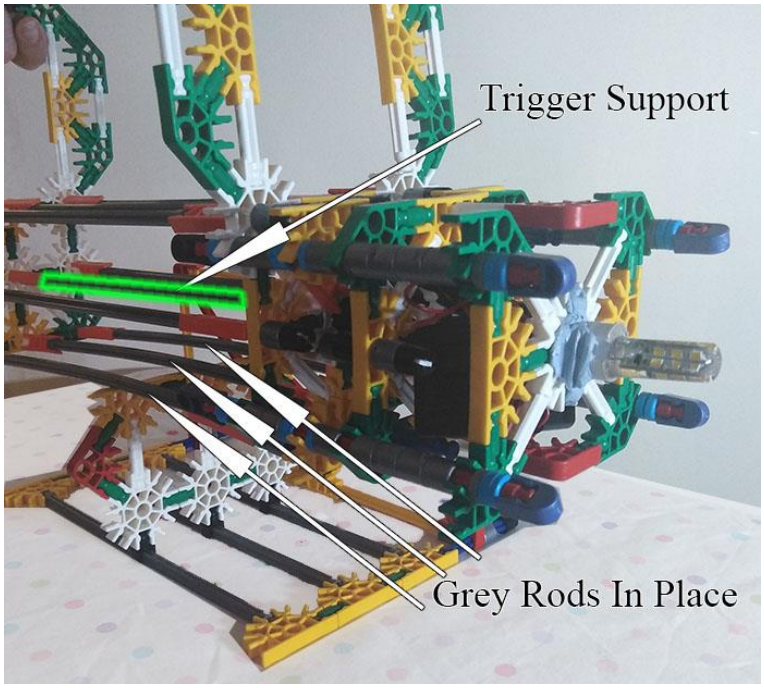


Figure 33 Dalén Lamp Mechanism[25]

The 'trigger support' in Figure 33, see above, is the centralised, rigid grey rod that holds the lamp in the 'off' position. The 'grey rods in place' prevent any contact between the centre rod and the cradle. In Figure 34, see below, the grey rods have been removed and the rigid grey rod exchanged for a flexible, green rod, allowing the green rod to bend and retract the switch, pulling it to the 'on' position.

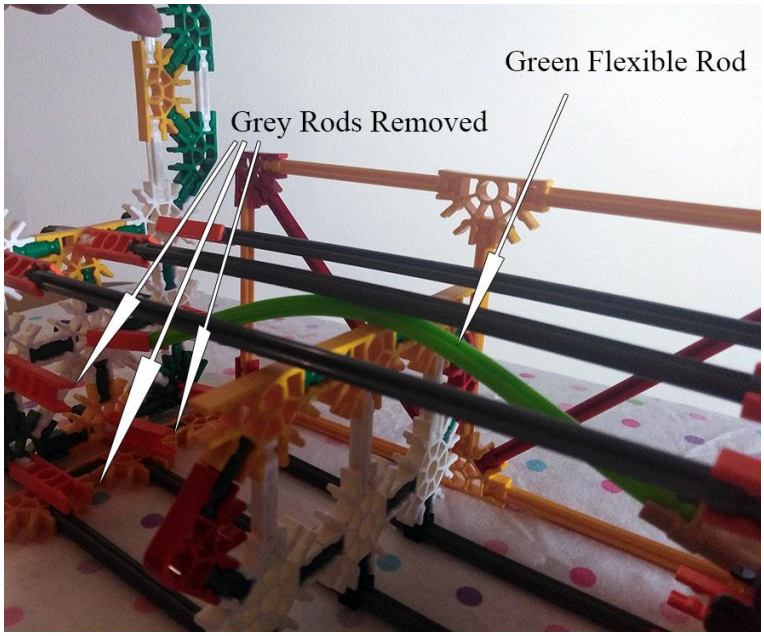


Figure 34 Dalén Lamp Mechanism

[25] The cradle was rebuilt to facilitate these illustrative photographs.

Now the K'Nex puzzle finally bears a conceptual resemblance to the original Dalén Light's operational mechanism. Instead of a single dark rod being surrounded by lighter coloured rods that react differently to a uniform force (light), a single flexible rod is surrounded by rigid rods that react differently to a uniform force (pressure). This starting position for the participants is the equivalent of Gustaf Dalén being given a proposed lighthouse flow valve, with the mechanism already assembled, but with every rod in the flow valve being the same (silver). Accessing the Clue 2 could help. Clue 2 reveals a written clue, as seen below in Figure 35.

Figure 35 The Dalén Lamp: Clue 2

Their final step was to allow access to the centre rod so that when the Lamp is pushed onto the cradle, the cradle bends the centre rod. The removal of rods that were below and/or parallel with the flexible rod allows this. The final clue is a K'Nex assembly, to be placed in the cradle, see Figure 36 below.

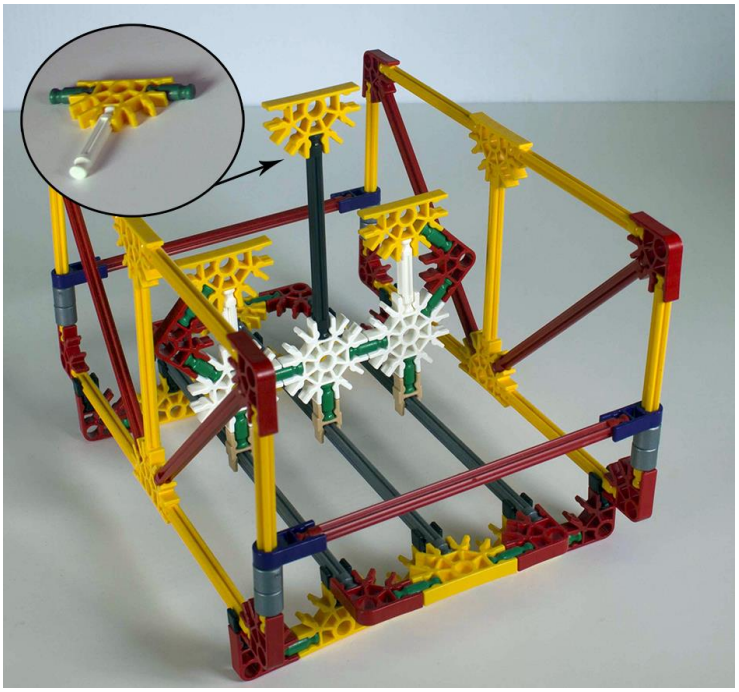


Figure 36 The Dalén Lamp: Clue 3

With this in place, the removal of only a single rod (the one directly below the flexible rod) facilitates a solution. But this clue was really a hint rather than a simplification, implying how to interact with the altered structure of the cradle.

Now, the participant simply holds the K'Nex Dalén Lamp above the cradle, with it being off. They lower it onto the cradle, where the flexible rod bends and releases the pressure on the switch, switching it on. Then, they lift it away from the cradle, where the flexible rod, no longer under pressure, immediately straightens and pushes the switch back in place, switching the K'Nex Dalén Lamp back off.

3.5.2 The Williams F1 Suspension System

Historical Problem: For the 1981 F1 Season, F1's Ruling Body introduced a new rule forbidding the use of any driver-operated, (or remote-operated), mechanical device to alter the ground clearance.

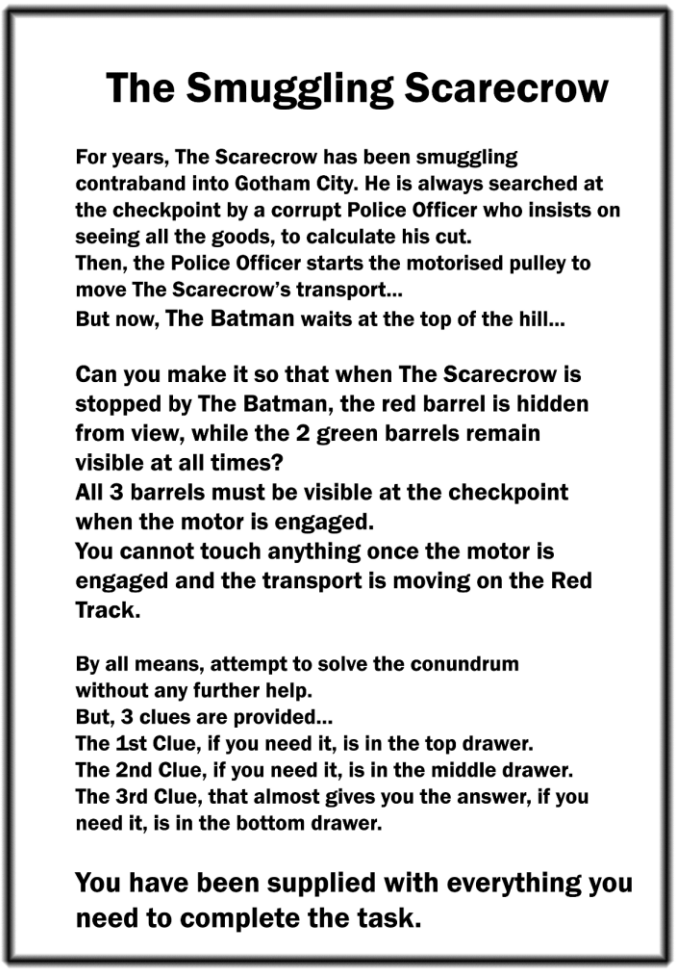
Historical Solution: The Williams Team's designer Gordon Murray circumvented this rule by designing a hydro-pneumatic suspension system connected to hydraulic fluid reservoirs. As the car went faster, aerodynamic downforce pushed the body lower on its suspension and the hydraulic fluid in each suspension strut was pushed out into the reservoirs (Cross 2003).

Original Designerly Thinking: The realisation that the natural forces of acceleration and gravity could be leveraged to produce much the same effect as the (now illegal) mechanically controlled ground clearance, see Table 29 below.

The William's F1 Suspension System	
Initial Problem	The F1 Ruling Body set a minimum ground clearance under all cars of 6cm. Driver-operated mechanical devices to alter the ground clearance were made illegal.
Impasse	Officials will check the clearance before and after the race.
Reframing	Natural downforce will push every car down, depending on speed. Can we somehow control this natural force selectively to manipulate ground clearance during the race, but allow the car to return to the 6cm ground clearance at standstill?
Insight	At speed, aerodynamic downforce lowered the car's suspension and hydraulic fluid in each suspension strut was pushed out into the reservoirs through a membrane. At cornering speeds, the membrane retained the fluid and suspension would stay low, but on stopping at the end of the race, the fluid would promptly return to the suspension struts.

Table 29 The William's F1 Suspension System

The student's first contact with each puzzle was by reading the printed design brief or problem-statement. The F1 problem brief was placed face down on the table next to the puzzle. They read the following, see Figure 37 below:



The Smuggling Scarecrow

For years, The Scarecrow has been smuggling contraband into Gotham City. He is always searched at the checkpoint by a corrupt Police Officer who insists on seeing all the goods, to calculate his cut.
Then, the Police Officer starts the motorised pulley to move The Scarecrow's transport...
But now, The Batman waits at the top of the hill...

Can you make it so that when The Scarecrow is stopped by The Batman, the red barrel is hidden from view, while the 2 green barrels remain visible at all times?
All 3 barrels must be visible at the checkpoint when the motor is engaged.
You cannot touch anything once the motor is engaged and the transport is moving on the Red Track.

By all means, attempt to solve the conundrum without any further help.
But, 3 clues are provided...
The 1st Clue, if you need it, is in the top drawer.
The 2nd Clue, if you need it, is in the middle drawer.
The 3rd Clue, that almost gives you the answer, if you need it, is in the bottom drawer.

You have been supplied with everything you need to complete the task.

Figure 37 The Smuggling Scarecrow: Problem Statement

It was presumed that undergraduate design students would not know of the internal workings of the William's 1981 F1 car. Even if they were familiar, the connection was too tenuous to be easily made. F1 was not mentioned until after their experience was over. This problem-statement was the 'wordiest' of the 3 puzzles. Several students commented this on during their participation and in interview, always in a negative way.

See Table 30 below for a description of the problem.

The K'Nex Version of: The William's F1 Suspension System	
Initial Problem	The participant must load a carriage with 3 barrels at the bottom of a steep hill. A checkpoint guard will check that there are 3 barrels. When the carriage gets to the top (under motorised control), the red barrel must be no longer visible. The participant may only touch the barrels/carriage while loading up at the bottom of the hill.
Impasse	Invisibility is impossible!
Reframing	Invisibility is impossible, but hiding is not…
Insight	The upward slope meant gravity could move the red barrel into a hidey-hole of some type, but gravity would be indiscriminate. Some way of protecting the green barrels from the effects of gravity must also be part of the solution.

Table 30 K'Nex version of The F1 Suspension System

The design of this puzzle was dictated by physics. The only safe, consistent natural force to leverage was gravity; therefore, it had to involve an incline or decline of some type. Figure 38, below, presents the first version of the Smuggling Scarecrow puzzle.

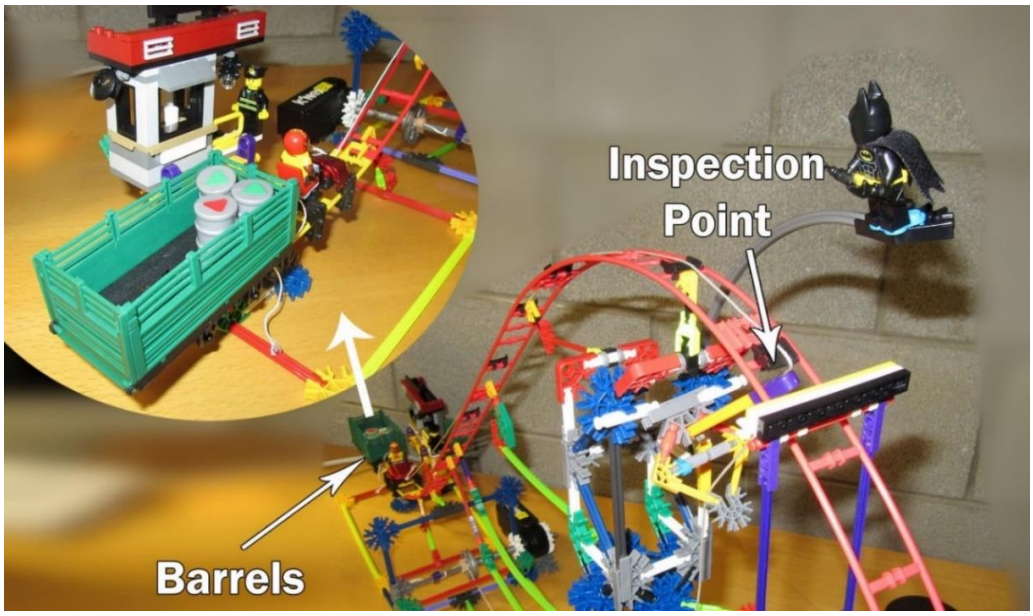


Figure 38 Initial Design: The Smuggling Scarecrow

In pre-testing, Tester 1 simply tied elastic to connect the cart and the red barrel and positioned it on the rear edge of the cart. It fell out as soon as the cart moved and was obscured (by the cart itself) when it arrived at the end, qualifying as a successful solve. So, the puzzle design was altered so that The Batman and The Policeman were always on the same side of the cart and the track was angled slightly so that this could no longer work as a solution, as the barrel would always fall out on the same side as The Batman.

Now, if the red barrel (which had to be visible to The Policeman at the start) subsequently fell out, it would always be visible to The Batman. The final version of the Smuggling Scarecrow puzzle is seen below in Figure 39.

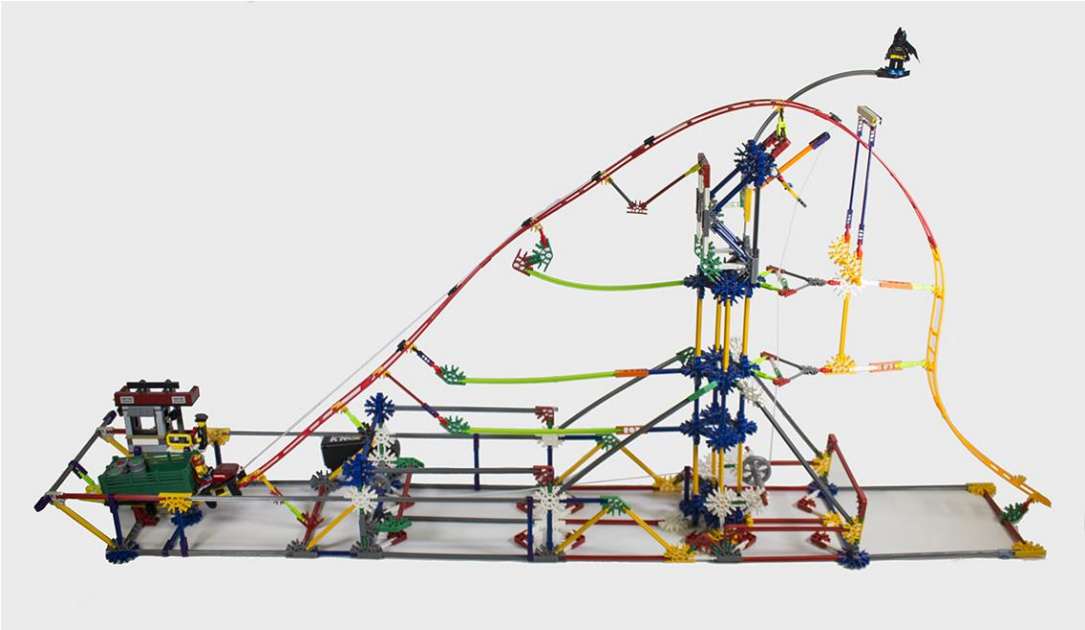


Figure 39 Final Design: The Smuggling Scarecrow

Participants had to present all three barrels to The Policeman at the checkpoint. It would be explained beforehand that there would be adjudication by the researcher (in the role of Facilitator). When participants said their solution was ready, the researcher would stand and look from The Policeman's viewpoint. If 'The Policeman' could see all three barrels, they could then activate the motor. The Scarecrow and cargo cart move onto the red track and cannot be touched again, see Figure 40 above.

Figure 40 The Policeman & The Scarecrow

When the cart reaches the top, the motor would be stopped, and the researcher would look from The Batman's viewpoint. If 'The Batman' could see the two green barrels but not the red one, the problem was solved. Figure 41, below, is not a solution, as The Batman can see all three.

Figure 41 The Batman, checking the barrels

There was a gear wheel, see Figure 42 below, under The Scarecrow's starting position. The white cord is what pulls the container and pressing that cord against the wheel results in the cord wrapping around the wheel, accelerating the container's speed significantly, although it was never a necessary step. However, no participants either asked about the gear wheel or attempted to use it.

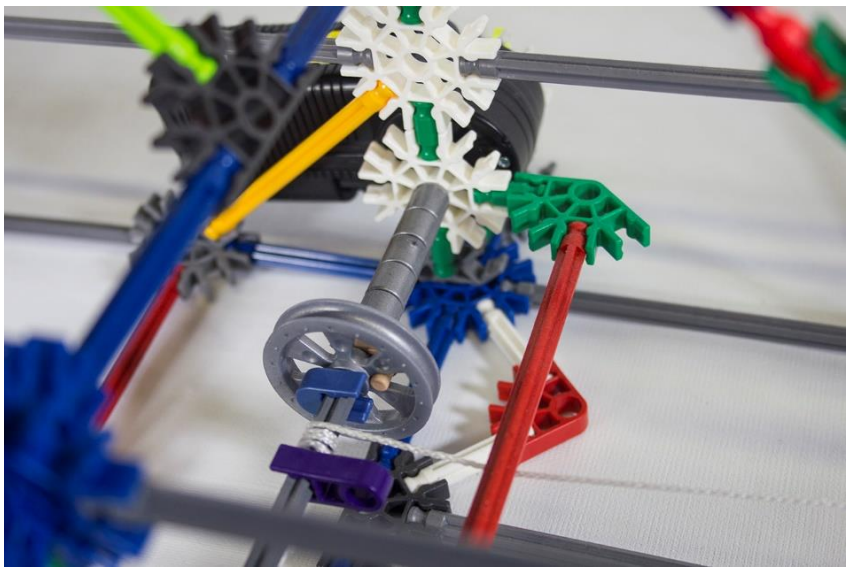


Figure 42 Gear Wheel

But, all three pre-testers had requested an explanation of the wheel's purpose, and so it remained in place. The researcher offers the explanation that the difference was the context; the pre-testers knew they were testing the mechanism and focused on that, rather than them being testing *by* the mechanism.

The clues were, as always, inside a set of drawers. Clue 1 was a written clue, see Figure 43, below.

Figure 43 The Smuggling Scarecrow: Clue 1

The next clue was more explicit. Clue 2 was a written clue, see Figure 44, below.

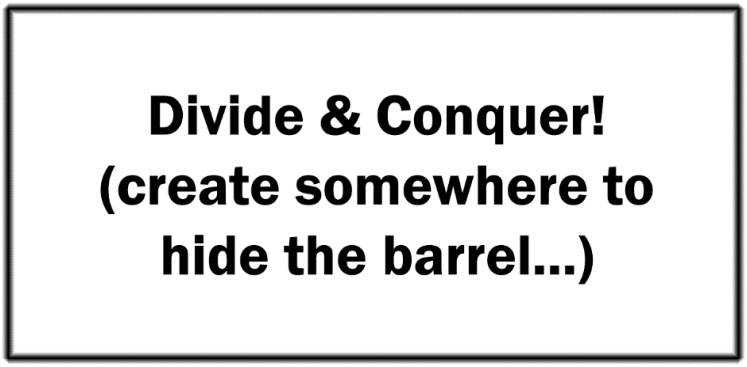


Figure 44 The Smuggling Scarecrow: Clue 2

All solutions[26] could be based on a false-bottom of some type and selective manipulation of the barrels to deal with the indiscriminate natural force of gravity, much as the Williams Team used acceleration to drive their pneumatic system and relied on gravity to return the car to being legal once stationary (for practical reasons, gravity replaced acceleration & gravity in this puzzle). If a participant got this far, they

[26] One participant managed to solve without a false bottom, and those details are presented in the Discussion chapter.

would often solve without any more help (50% of solvers did not access the 3rd clue). If they were struggling to realise their solution, Clue 3 was a scaled diagram of a simple solution, see Figure 45 below. It was exactly the same size as the profile of the cart, but if this were not obvious to the participant, it would be pointed out. When they placed it against the side of the cart, they would hopefully know what they should build. Taking some card, cutting it to size and bending it into shape results in a simple solution.

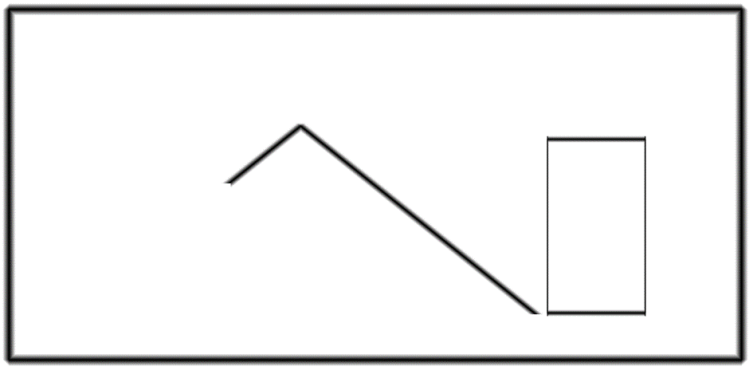


Figure 45 The Smuggling Scarecrow: Clue 3

3.5.3 The New York Elevator

Historical Problem: In a multi-storeyed office building in New York, occupants complained about the waiting times for elevators. Because of the age of the building, no engineering solution could be justified economically.

Historical Solution: The designers installed mirrors in the elevator boarding areas so that those waiting could look at themselves (or each other) without appearing to do so. The complaints about waiting stopped.

Original Designerly Thinking: The designers realised that the waiting times were only a little longer than the modern elevators in other buildings. They concluded that the complaints might be just a consequence of boredom, rather than an absolute need for a faster journey. If so, then alleviating the boredom would be a solution, rather than the prohibitive solution of speeding up the elevators.

This example is often given in lecture to design students of all types and is seen as an excellent example of 'reframing the argument' and 'thinking outside the box'. It was the only puzzle that the participants would probably recognise, because they may have heard it described in lecture and the K'Nex version's form factor was similar. It was also designed to be the simplest puzzle to solve conceptually, even though it had the most complex physical structure. Obviously, the real-life solution involved dealing with boredom, an emotion (and its resolution) beyond the scope of pieces of interlocking plastic. But this puzzle remains inspired by The New York Elevator: it retains the need for reframing, it retains the same impasse, but simplifies the requirements of any solutions, see Table 31 below.

The New York Elevator	
Initial Problem	The elevator is too slow!
Impasse	Speeding it up is not a viable option.
Reframing	Instead of speeding up the elevator, make waiting more interesting.
Insight	Mirrors in the lobby will make the wait not seem as long.

Table 31 The New York Elevator

The printed design brief, or problem-statement, is reproduced as Figure 46, below.

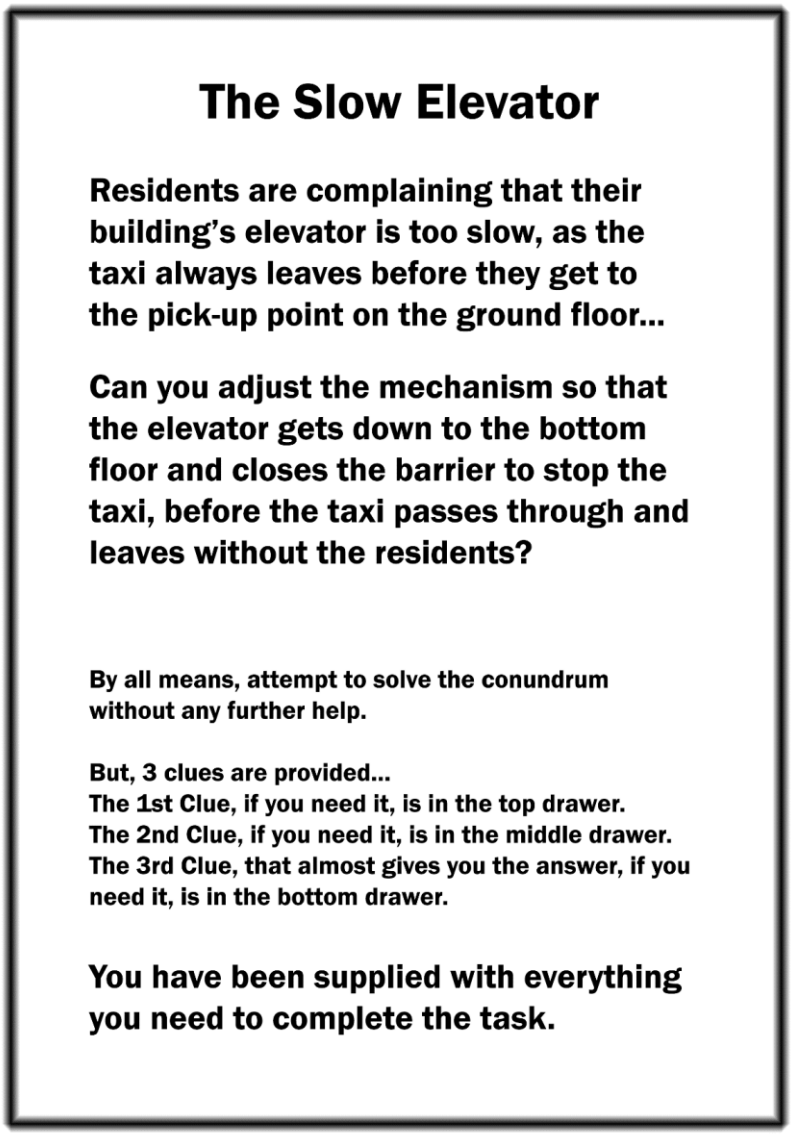


Figure 46 **The Slow Elevator: Problem Statement**

The design thinking for this puzzle is discussed in Table 32, see below.

The K'Nex Version of: The New York Elevator	
Initial Problem	The elevator's descent from the top triggers the taxi. The elevator's arrival at the bottom triggers the gate that parks the taxi in the correct parking place.

Impasse	The elevator takes 26 seconds to descend to the bottom. The taxi takes 11 seconds to get to the bottom and speed past the correct parking place. Any efforts to speed up the elevator, or to slow down the taxi, fail.
Reframing	If you can't speed up the elevator, and you can't make the taxi slower, what else is there?
Insight	Breaking the synchronisation between the taxi and elevator starting their journeys at the same time is a key step.

Table 32 K'Nex version of The New York Elevator

The initial form of the design of the elevator held through its iterations, see Figure 47 below. The changes that were made because of pre-testing were to ensure a standardised experience for every participant. The structure of the taxi's start position was rebuilt to be more robust and consistent. Depending on how heavy-handed the tester was when placing the taxi (Tester 2 again), the starting position of the taxi could affect the speed of the taxi, usually slowing it so that it stopped hallway down.

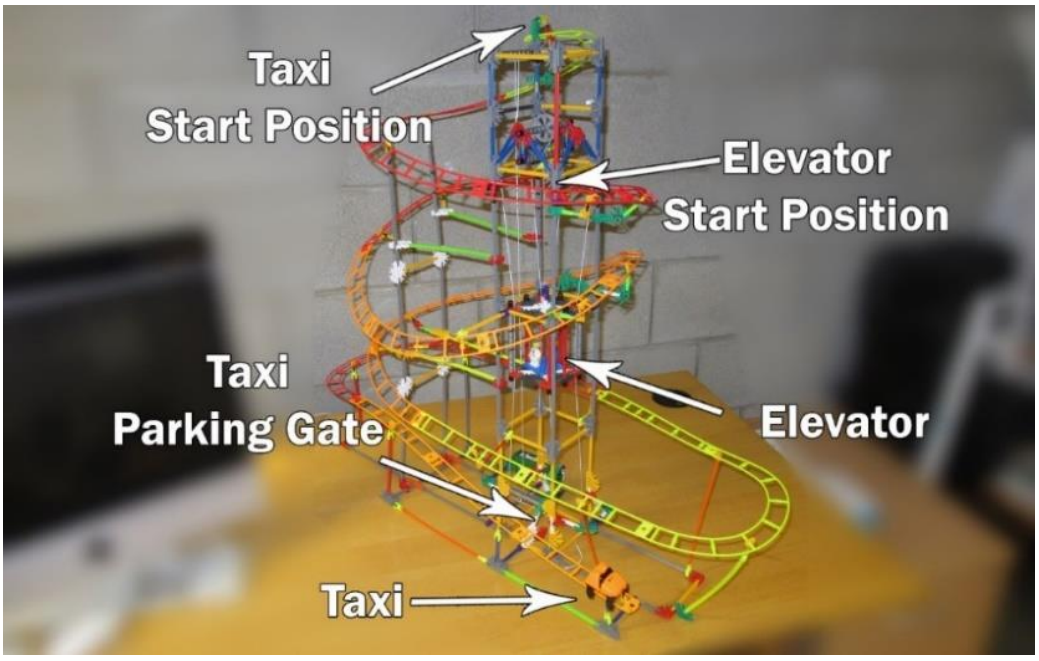


Figure 47 Initial Design: The Slow Elevator

The final design is presented in Figure 48, see below.

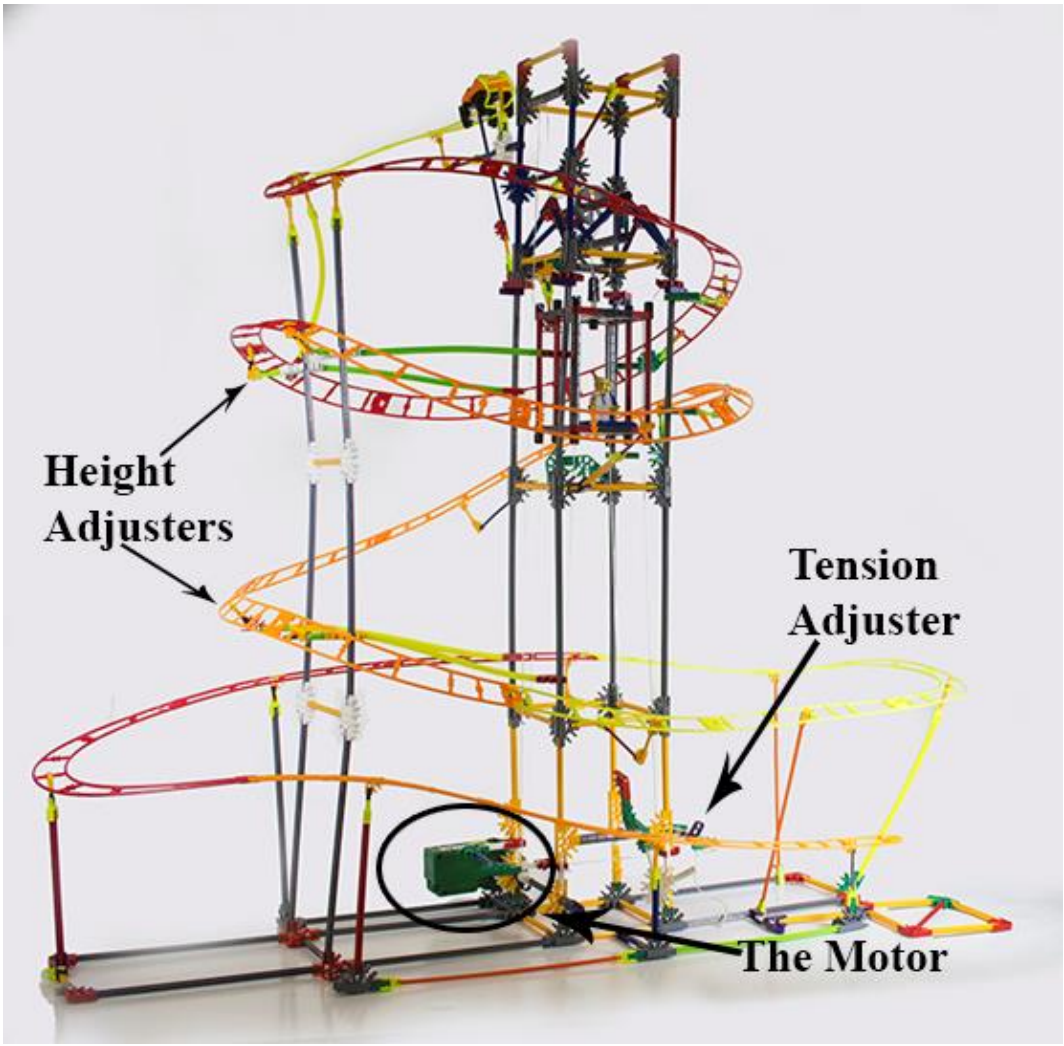


Figure 48 Final Design: The Slow Elevator

If, as expected, participants began with a deductive approach (Ash and Wiley 2006), there would be an effort to either speed up the elevator and/or slow down the taxi.

The motor is bi-directional, but single speed. Switching the motor on either lowers the elevator or brings it back up. The heights of the tracks were adjustable at several positions on the track and altering the track heights would change the taxi's rates of acceleration, see Figure 48 again, above. The tension adjuster loosens the elevator's guidance cables. Loosening the cables can marginally increase the elevator's speed, but this lessening of resistance only speeds up the elevator's descent by 1.5 seconds.

However, the tightened cables do provide a smooth ride down. Slackening them meant that the elevator has a rough, shaky ride down. This would interfere with some of the

possible solutions. As the fully slackened cables only result in a marginally faster travel time of 24.5 seconds, it is of no practical gain, see Figure 49 below.

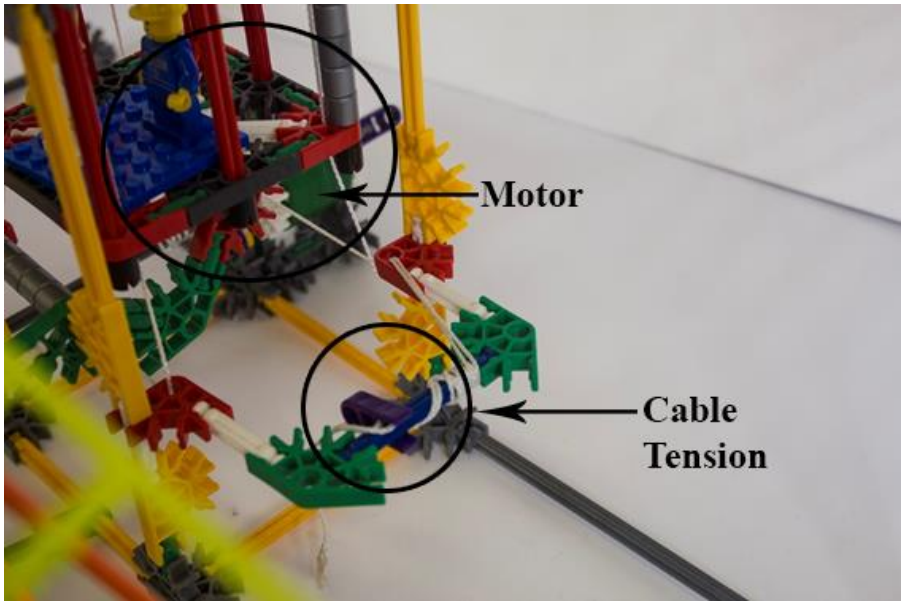


Figure 49 Motor & Cable Tensioner

The taxi was not powered, owing its speed to gravity and the angles of its pathway. An obvious step is to try and extend the distance it must travel. This is not possible as no extra track pieces were supplied and if participants asked for more pieces, this request was denied. To prevent an overall speed decrease being a viable solution, an immovable part of the track was angled so that any slowing down of the taxi would result in it not having enough acceleration to get over that hump in the track, see Figure 50, below.

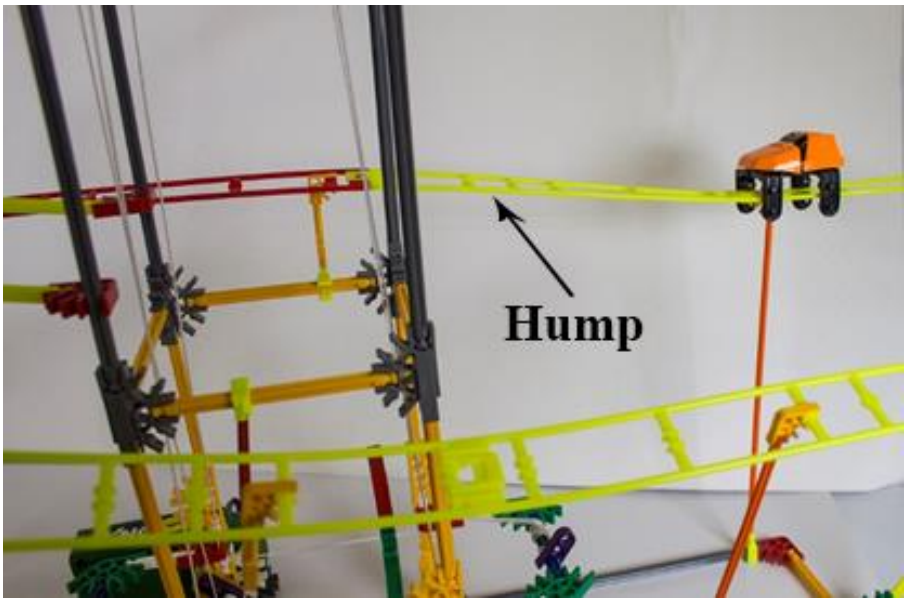


Figure 50 The K'Nex Speed Bump

Figure 51 The K'Nex Barrier

The taxi takes 11 seconds to reach the white K'Nex barrier on the 'ground floor', see Figure 51 above. However, that barrier is only pushed into place by the arrival of the elevator. Until the elevator arrives at the ground floor, the barrier is below the level of the track and is ineffectual. When the motor is engaged, the elevator descends and releases the barrier holding the taxi. In Figure 52, below, we can see the start position.

Figure 52 Start Position of The Taxi

Figure 53, see below, shows the mechanism just after release. When the motor is engaged, the elevator descends and immediately triggers the taxi's release, which quickly overtakes the elevator in a race to the bottom.

Figure 53 Elevator Release

The clues were as follows, although these were accessed much less often than the clues for the other puzzles (8 participants solved it without accessing any clues).

Clue 1, see Figure 54 below, stated something all participants should know, but served to guide their thoughts, to plant the idea that as the speed couldn't be changed and the distance couldn't be altered, they would have to become unreasonable in their behaviour.

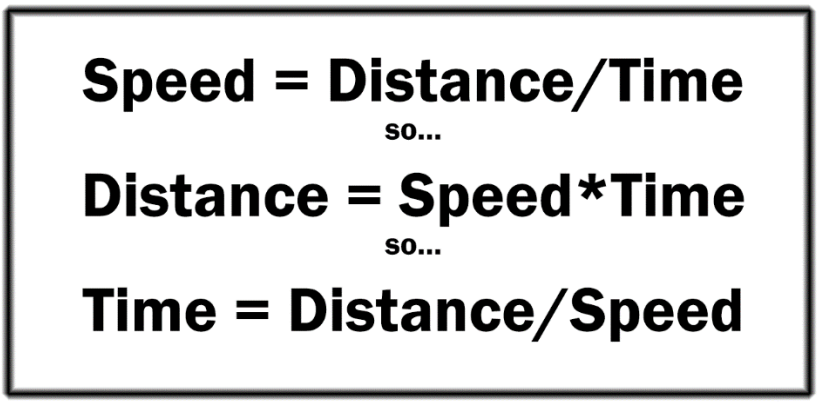


Figure 54 The Slow Elevator: Clue 1

Clue 2, see Figure 55 below, was a reminder that reframing was about realising what were the invariants, and what were not the invariants (Chu and MacGregor 2011). The initial problem statement presented the taxi and elevator as having to leave at the same time, not because it explicitly said it, but because the mechanism dictated it. The clue suggested that it did not have to be that way.

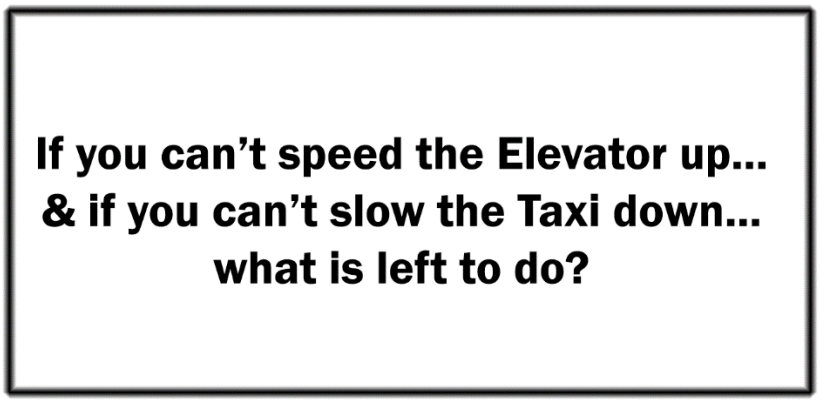


Figure 55 The Slow Elevator: Clue 2

The parts required for this solution were in the slot for Clue 3, see Figure 56 below.

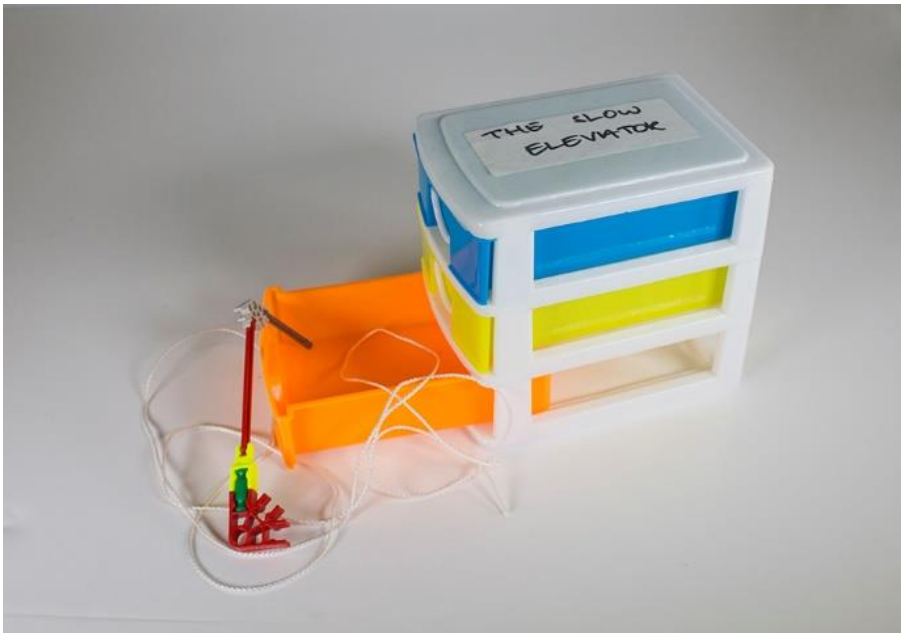


Figure 56 The Slow Elevator: Clue 3

It functioned as a hook, to replace the existing trigger, which should now be dissembled. The grey K'Nex piece was placed on the taxi and tied by the string to the top of the

elevator. When the elevator got to the bottom of the shaft, the string (cut to the exact length) would get taut and tug on the hook, releasing the taxi.

67% of those who attempted the puzzle solved it. Most came up with essentially the same solution, delaying the releasing of the trigger by lengthening the pieces of the trigger so that it remained in contact with the elevator for longer, and so the taxi was held in place for longer. In pre-testing, one of the testers successfully used the 3rd clue to realise a solution, but only after seeing it and imaging its application. The other two testers solved it in much the same way as the future participants would. Figure 57, below, shows the solution that most solvers would eventually produce.

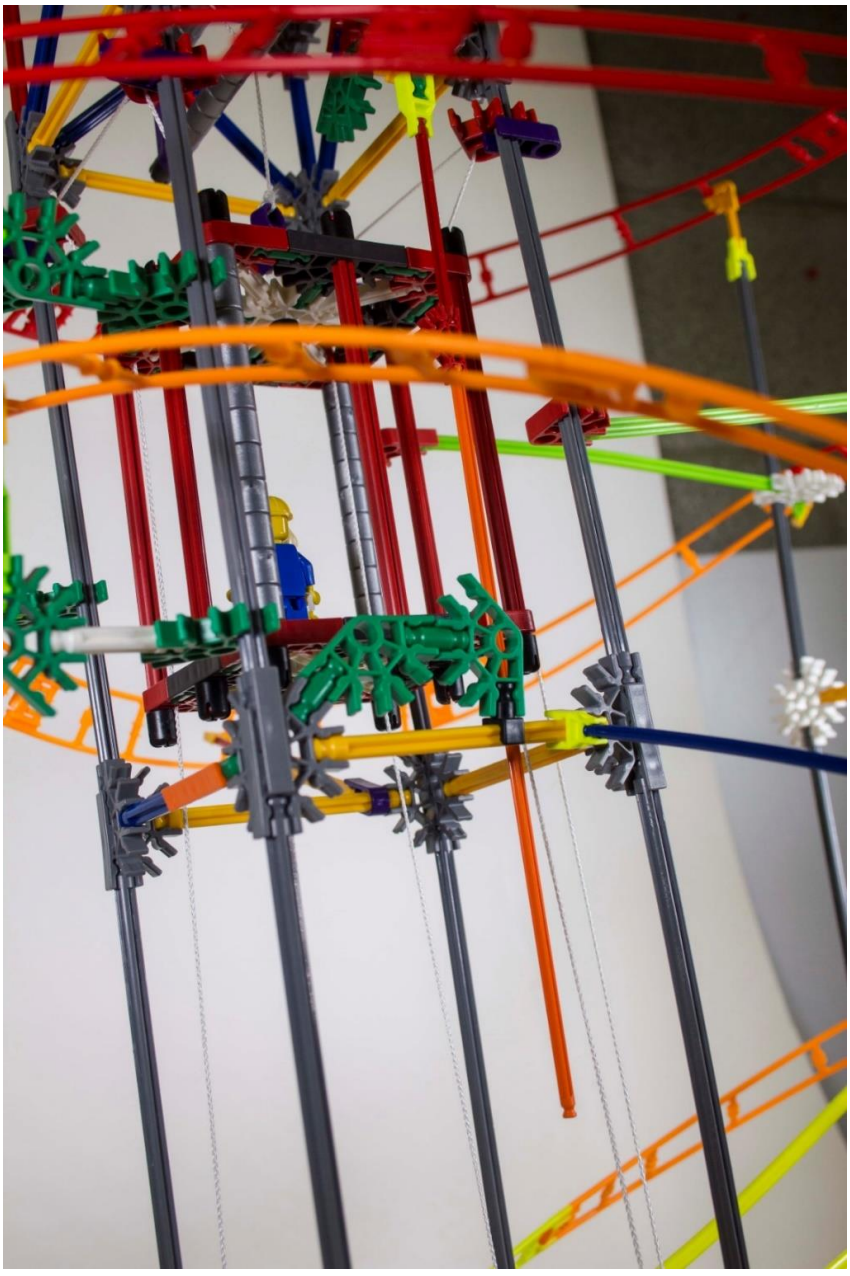


Figure 57 The Slow Elevator: A Popular Solution

In Figure 58 below, the red and orange K'Nex structure is the correct length for a solution. The purple and blue K'Nex structure is too short, and the taxi speeds past the barrier a second before it is raised.

Figure 58 Too short, or just right

Any structures longer than the red and orange would mean that the elevator would still be holding the trigger in place even after it arrived at the bottom of the shaft, never releasing the taxi.

The path to solution for the original New York Elevator problem was when the designer realised that the complaints were a result of boredom. This was after engineers reported that speeding up the elevator was not feasible. That is what prompted the 'reframing' of the problem. Here, participants could assume the engineer's role, and fail. Then, they would have to reframe the argument, eventually realising that the initial invariant of elevator/taxi synchronisation could be changed into a variant by making a thoughtful adjustment to the structure (Thomas and Carroll 1979).

3.6 Pre-Testing the Pedagogical Environment

Pre-testing of the puzzles and the decision-making process regarding this pedagogical environment were originally centred in the Computer Science Department's Design Studio. It was obvious that testing would have to be in-term[27], but that meant that the Design Studio would also be in use as a teaching space and a meeting space for faculty. It could also be booked by postgrads for meetings, workshops, interviews, etc.

[27] Out-of-term testing would mean no student participants.

Figures 59 and 60, see both below, are from the puzzle set-ups and camera testing, to work out the timings for setting up the puzzles and recording equipment, including the best compositional framing for the video recordings.

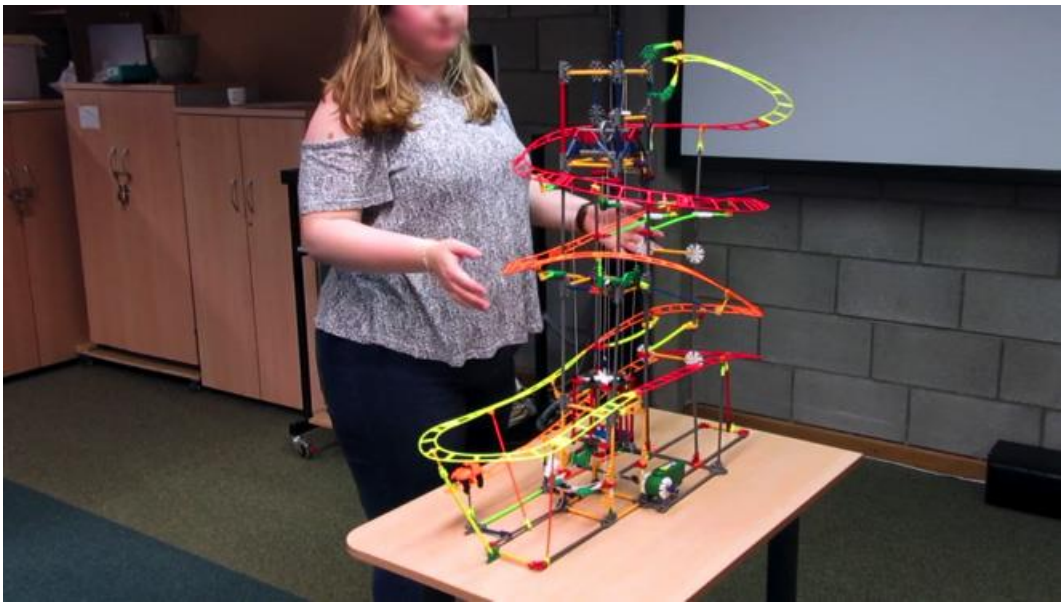


Figure 59 Pre-testing

Figure 60 More pre-testing

The compromise decision to use a single camera setup was to reduce set-up and takedown times. While the first recording session went well, it became obvious that the set-up would have to be adjusted.

Figure 61 is a screen capture of Participant 1 (P1) in action.

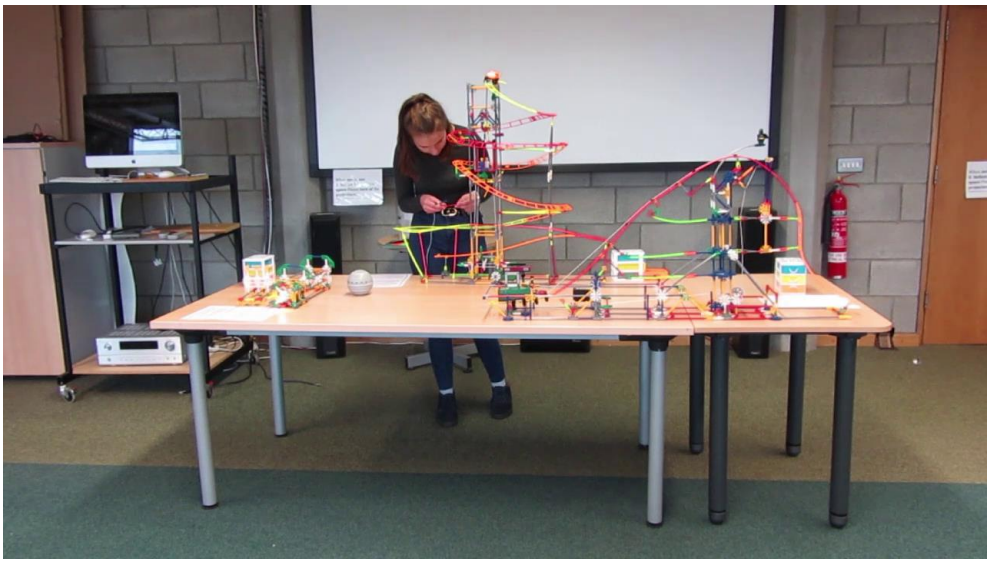


Figure 61 P1 in action

When P1 worked on the Smuggling Scarecrow puzzle, she was often directly between the camera and what was of interest, see Figure 62 below.

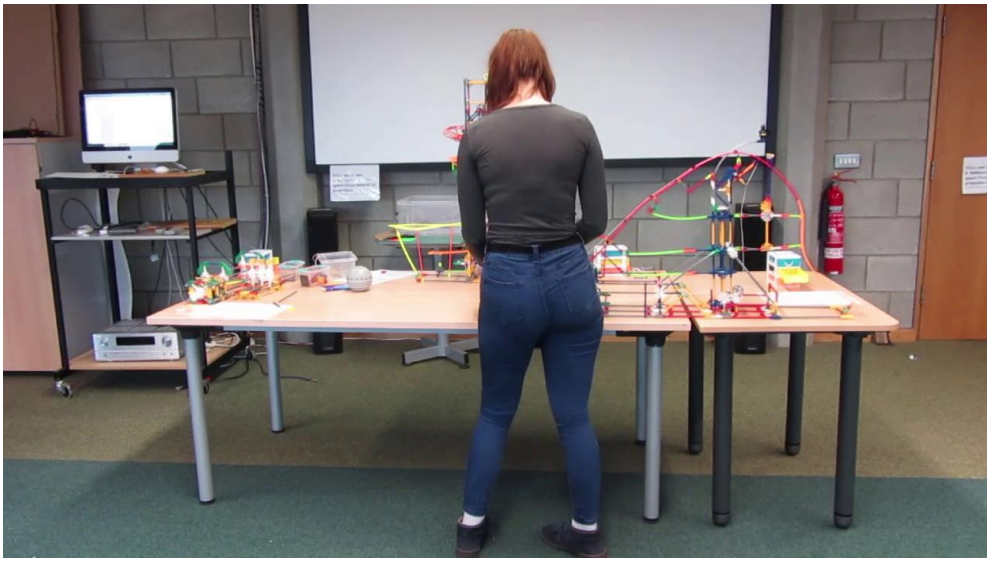


Figure 62 P1 obscuring the action

When this happened, to observe and take notes meant the researcher had to move around the testing area, trying to stay out of the camera-shot if possible. P1's activity was a pilot study of sorts, although it was always intended to include the data from P1 as part of any findings, as the puzzles had already been fully tested. The piloting element was to finalise workflow and its timings, i.e., puzzle and camera set-up,

carrying out of the testing, breakdown of equipment to clear the room, checking and backing-up the recording, etc. While a multiple camera set-up would be desirable, the logistics of this, considering the limited time frames available, made it unrealistic.

While the Design Studio was bookable, on two occasions in the following week, faculty members were holding meetings in timeslots booked for testing with participants. While these faculty members were always very supportive, they had not checked the booking system when making their arrangements. As the data-gathering phase of this research project was at the mercy of participant goodwill, arranging timeslots and then cancelling them would become an issue for participant recruitment.

Then, a desk in the researcher's office became available. So, a 4-camera set-up was permanently set-up to surround the puzzles, and the participants could now come to a controlled environment for this pedagogical exploration. To recruit participants, a single-page web site (www.designwisdom.org) was created, see Figure 63 below, and the classrooms of the Interaction Design cohort (Digital Media Design & iMedia) were visited.

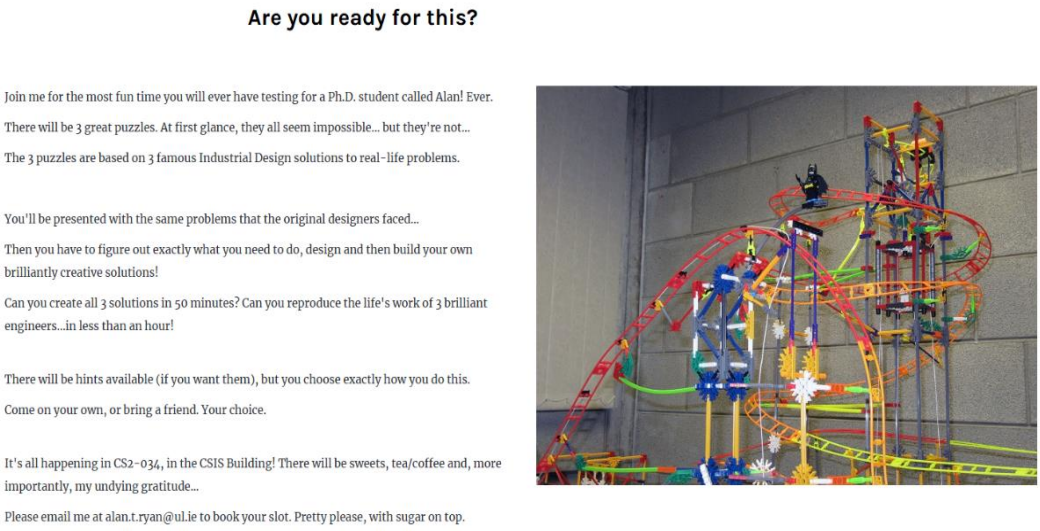


Figure 63 Screencap of Recruitment Webpage

A brief presentation was made, explaining that there would be puzzles to solve as part of a research project. On request, the course director of UL's Industrial Design program (Production Design & Technology) emailed his entire undergraduate cohort the URL and made a similar request for participation.

3.7 Participant Details

All 31 students who volunteered were design students, see Table 33 below. Given the free choice, 19 chose to participate individually, and 12 choose to participate as 6 pairs.

Year of Study →	**1st**	**2nd**	**3rd**	**4th**	**Masters**
Interaction Design	3	3	8	9	5
Industrial Design				3	

Table 33 Breakdown of the 31 Participant Profiles

The 19 participants who chose to participate individually and the 12 who chose to participate in pairs are now described in more detail. Interaction Design is designated 'DMD' and Industrial Design is designated 'PDT'. The Interactive Media Masters course is designated 'iMedia'. As the relevancy of the participant's skill level with K'Nex become apparent during data analysis, it is included here. 'K'Nex Skill' (self-declared) has been classed as 'Low, Medium, or High'.

'Solves' is the amount of puzzles the participant solved. Any solving of an insight puzzle by definition involves a successful reframing, so 'Reframes' is how many successful reframes were made, including the reframing of any puzzles that they solved. While a puzzle solve was clear, reframing without a solve was less so. Confirmation of reframing without solving was either through the video record, where participants articulated an acceptable reframing, or revealed during their subsequent interview.

'X' means the student deliberately excluded information when completing their AMS survey, and their choice is respected. An additional category is included for the paired participants. 'Relationship' is a general descriptor of their relationship with each other.

See Table 34 below for those design students that participated on their own.

	Course	Year	Age	Gender	K'Nex Skill	Solves	Reframes
P1	DMD	4	22	Female	Medium	3	3
P2	DMD	4	22	Male	Medium	1	2
P3	DMD	4	22	Female	High	0	3
P4	DMD	1	18	Male	High	0	2
P5	DMD	4	21	Female	Low	2	3
P6	DMD	4	22	Female	Medium	1	2
P7	DMD	4	21	Male	Low	0	1
P8	DMD	1	21	Male	Medium	2	3
P11	DMD	4	22	Male	Medium	2	3
P12	iMedia	1	25	Male	High	1	2
P13	DMD	1	22	Male	High	0	1
P14	DMD	3	28	Male	Low	1	2
P19	PDT	4	22	Female	High	2	3
P20	DMD	2	X	Female	Medium	3	3
P21	DMD	3	22	X	High	2	2
P22	PDT	4	22	Female	Medium	0	1
P25	DMD	3	21	Male	High	1	2
P28	PDT	4	22	Female	High	2	3
P31	DMD	3	20	Female	Medium	2	2

Table 34 Single Participants

See Table 35 below for those that participated in pairs.

	Course	Year	Age	Gender	K'Nex Skill	Solves	Reframes	Relationship
P9	iMedia	1	X	Female	Medium	1	2	Friends
P10	iMedia	1	25	Female	Low	1	2	Friends
P15	DMD	4	45	Male	High	2	3	Friends
P16	DMD	4	21	Female	Low	2	3	Friends
P17	DMD	3	22	Female	Low	2	3	Best Friends
P18	DMD	3	20	Female	Medium	2	3	Best Friends
P23	iMedia	1	24	Male	Medium	2	3	Best Friends
P24	iMedia	1	24	Female	High	2	3	Best Friends
P26	DMD	2	20	Male	High	1	2	Best Friends
P27	DMD	2	21	Female	Medium	1	2	Best Friends
P29	DMD	3	20	Female	Low	2	3	Best Friends
P30	DMD	3	21	Female	Medium	2	3	Best Friends

Table 35 Paired Participants

Two of the undergraduate 'single' participants (P14 & P20) were mature students, as opposed to the majority whose route to university was directly from 2nd level school.

One of the 'paired' participants (P15) was a mature student in DMD, as opposed to the other seven 'paired' DMD students whose route to university was directly from 2nd level school. The five iMedia students (P12, P9 & P10, P23 & P24) were from varied backgrounds.

The three Industrial Design students included were the only respondents from that entire cohort. The argument made for their inclusion is that the problems that they face as designers are similar in nature to those experienced by Interaction Designers, at least regarding their design thinking processes. For example, all three physical puzzles presented here are representations from the Industrial Design disciplines. Yet, they are often given in Interaction Design classes to illustrate 'design thinking' and 'problem reframing'. The fact that these problems and solutions are not directly applicable to Interaction Design is never considered relevant.

All eight participants who were not directly from second-level schooling had a profession/degree, and this is detailed in Table 36, below.

	Course	Year	Age	Gender	Profession/Degree
P9	iMedia	1	X	Female	Interior Design
P10	iMedia	1	25	Female	Engineering
P12	iMedia	1	25	Male	Industrial Design
P14	DMD	3	28	Male	Fine Art
P15	DMD	4	45	Male	Painter & Decorator
P20	DMD	2	X	Female	Model Builder/Artist
P23	iMedia	1	24	Male	Creative Arts (Computer Science)
P24	iMedia	1	24	Female	Fine Art

Table 36 Mature Student Participants

The iMedia students' backgrounds were more varied than the undergraduates, regarding their knowledge-base and professional experience. Only three of the undergraduates were 'mature students' with a previous profession.

When participants arrived at the testing environment, the only information they had was from the web site and the brief presentation. So, it was repeated that the three puzzles were based on three famous Design solutions to real-life problems (but without going into any further detail), and that they would be presented with simulations of the

problems that the original designers faced, would have to figure out what to do, and then create and build their own solutions.

The participants, on arrival, were offered tea or coffee, refreshments to "soften the formality of the process" (Mannix McNamara 2010, p.88). They were given the practice K'Nex piece to remind them of how K'Nex works (or to introduce them to K'Nex in a very small amount of cases). Most participants declared a familiarity with the K'Nex system, having played with it as children. While this had been expected, the precaution of facilitating a brief refresher course was taken. As illustrated below in Figure 64, each participant was presented with a simple K'Nex construction and a box of parts and asked to recreate the construction.

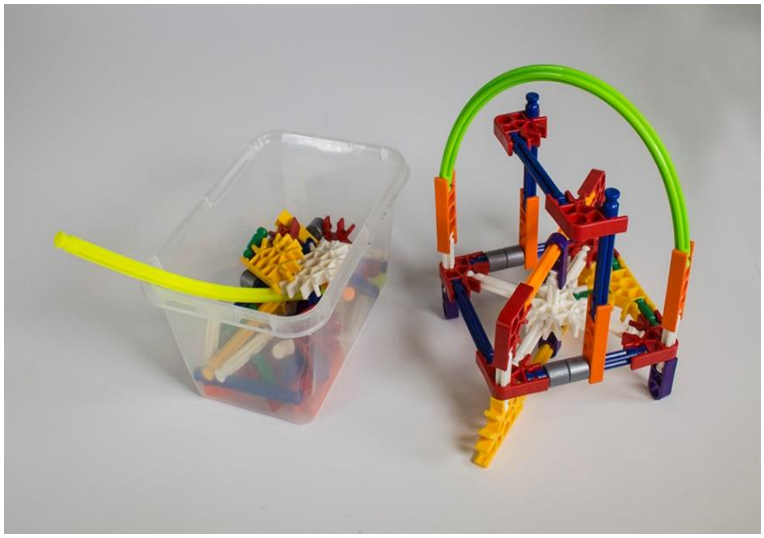


Figure 64 K'Nex 101

After 3-5 minutes, they all produced the following, see Figure 65 below.

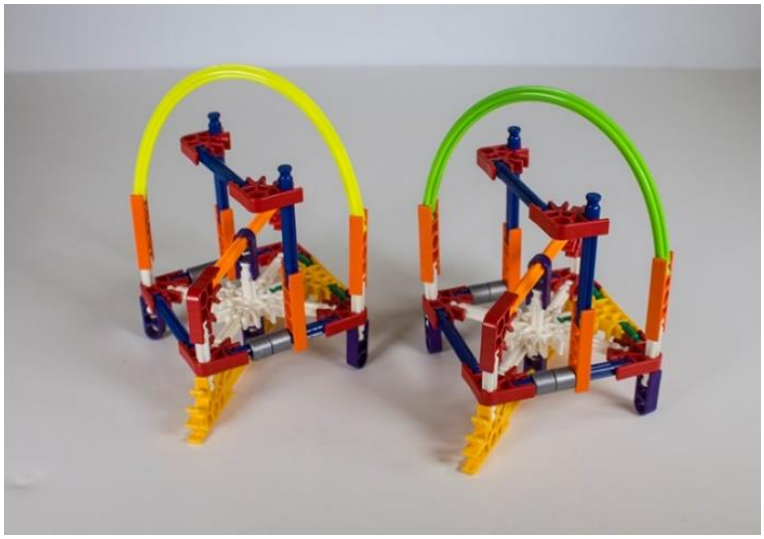


Figure 65 Results of K'Nex 101

This practice piece was designed so that it would involve every type of K'Nex connection, including a flexible piece. This was especially relevant for The Dalén Lamp and would serve as a hint. When they were ready, they were directed to the table with the 3 puzzles, see Figure 66, below.

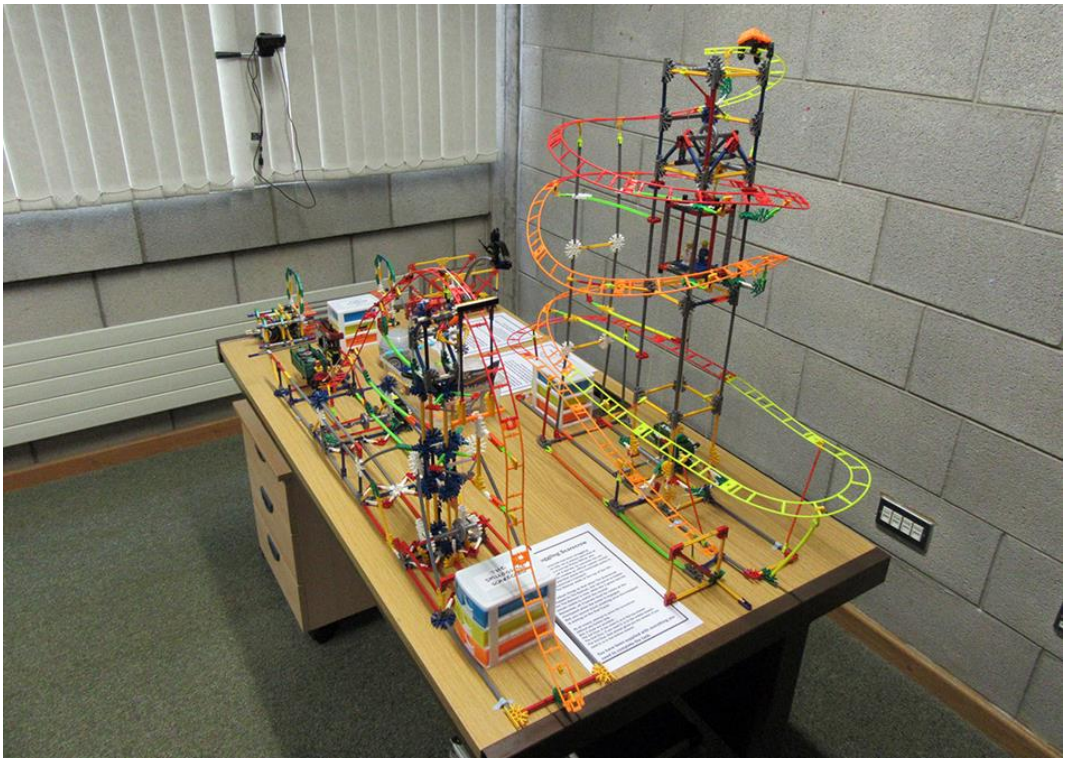


Figure 66 The Testing Table

Also, on the table were the three problem statements, and sheets of card, a scissors, Blu Tack, sundry items of a craft nature (string, paper clips, etc.) and a comprehensive selection of K'Nex pieces, see Figure 67, below.

Figure 67 Craft Supplies

3.8 The Externalising of an Internal Process

Scans and fMRIs are indispensable in medical applications and have helped scientists understand so much about the brain. But the mind remains a black box, in the sense that theories about how people think and feel will have to remain being based on the analysis of external, observable activities (Smallwood and Schooler 2006). In this thesis, the chosen methods that provided data for analysis were a mix of quantitative and qualitative methods. Here, the observable activities were their puzzle-solving activities (recorded on video), the AMS survey they filled out immediately afterward and the subsequent semi-structured interviews with all participants.

Video recording was chosen as a research method because it allows for the repeated viewing of 'moments', to enable an analyst to unpack the details of the activities of participants (Pentimalli and Spreafico 2016).

The Academic Motivation Scale was chosen as its theoretical foundation is Self-determined Learning and because research has shown that autonomous motivation predicts persistence and performance, especially on heuristic tasks that involve creativity (Amabile 1979; Sheldon 1995; Hennessey 2000).

The qualitative method of conducting semi-structured interviews and using a thematic analysis approach was chosen, as thematic analysis (TA) enables a focus on meaning across a data set. The objective of TA is never to discover and examine unique experiences, but to make sense of collective, shared meanings (Braun *et al.* 2018).

All forms of data collection are selective and video recordings are no exception. Where you position the camera, the number of cameras you use, whether you attempt to follow the action or use a fixed position, how you record the audio, all of these have an impact on the data collection itself and the subsequent analysis (Heath and Hindmarsh 2002). The focus on the action by the camera depends upon the analytic needs, as well as the practical constraints of the setting. As you compose with the camera to capture all possible activity, you can lose the details of their behaviour. Video recording always involves this compromise. Multiple cameras can help overcome these difficulties, as in this exploration's setting with participants either blocking the camera's viewpoint or being obscured by the puzzles. It must also be considered how this method of data collection might alter the behaviour of participants (Heath *et al.* 2010).

A 4-camera setup allowed for reviewing the participants' activities, with the planned expectation that at least one camera would always have a clear view of the participants' activities, with no activity missed because of the participant's body or a K'Nex puzzle obscuring it. In Figure 68, below, the bottom-left and top-right camera-angles are obstructed, but the other two angles are revealing.

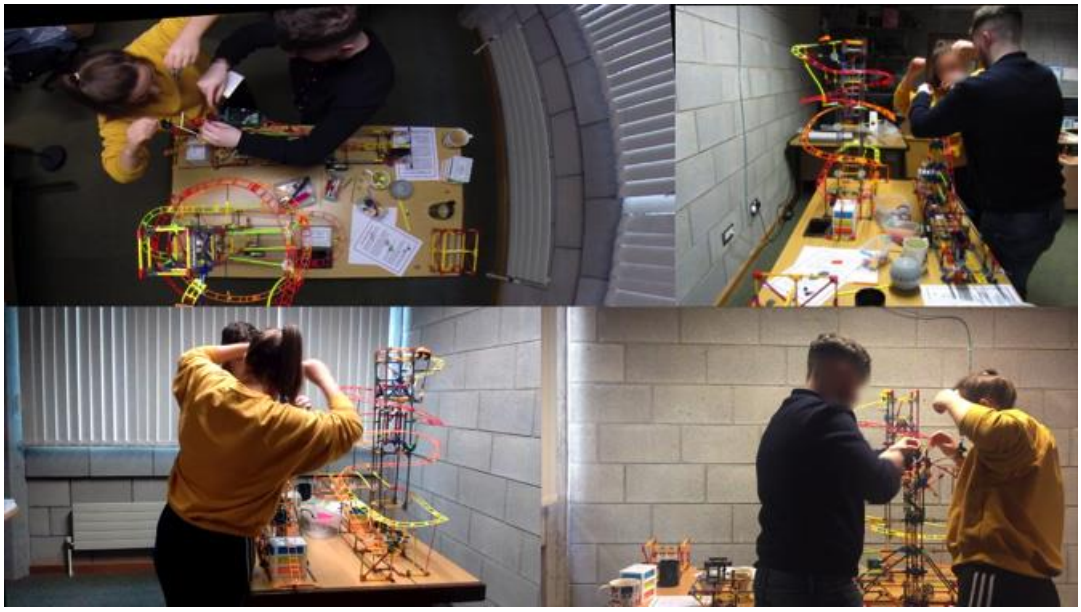


Figure 68 P26 & P27 in action, again

Although the data analysis from the video recordings was quantitative in nature (the exact timings of visible actions), any theory-based analysis of this data would have elements of subjectivity. To reduce the influence of that subjectivity, to produce rigorous and defensible findings, a process of watching and re-watching the videos of their performances was undertaken, resulting in exhaustive records of their activities. In addition, colleagues were invited to perform their own analysis, to confirm (or not) the researcher's analysis. The analysis of the video data is discussed in chapter 4, and the data (in spreadsheet form) is provided in the Appendices.

This is no suggestion here that successful performance in this exploration is definitive proof of strong design ability. But a core feature of design ability is the ability to employ abductive logic and/or appositional thinking (Cross 1990). The purpose of this research was to create an opportunity for Interaction Design students to engage cognitively and emotionally in a pedagogical environment, to explore new ways of introducing them to an abstract design concept, specifically reframing.

3.9 Not-Touching, Touching, and Building (NtTB)

This analysis of the video recordings of participant activities was a search for any patterns regarding performance and individual methods employed, from the following perspectives:

1. Constructionist Perspective: To understand how the physical nature of the puzzles affected their solving strategies (Vallée-Tourangeau *et al.* 2016).
2. SDL's Competence: To understand how presenting a way of their gauging their 'competence', would affect their strategies (Deci and Ryan 1985).
3. SDL's Relatedness: To examine how they 'related' to the Facilitator, and/or their partner (or not), and how these freedoms determined their solving strategies (Järvelä *et al.* 2016).
4. SDL's Agency: To consider what they did with their agency, their freedom to move at will from puzzle to puzzle, to choose their own path, to access clues (or not) (Reeve and Tseng 2011).
5. Learning Styles: To understand if Learning Styles had an impact on how these participants solved/learned (Eftekhar and Strong 1998; Geake 2008).

Coding refers to a thoughtful characterization of the actions. The presumptive nature of creating codes for the activities of others can easily lead to "uninterestingly abstract" findings, if the hypothesis-imposed criteria disregards what was relevant to the participants (Knoblauch et al. 2006, p31). The following codes were generated *after* repeated viewings of the recordings, attempting to code all their activity over the 45 minutes. Their physical interactions with the puzzles were classified into three observable categories: Not-Touching; Touching; and Building defined as follows:

1. *Not-Touching* was when the participant was not touching a puzzle.
2. *Touching* was when the participant was touching or playing with a K'Nex piece, or manipulating the puzzle to see how it worked, to explore and gather information. This category included turning on a motor and studying how the puzzle's mechanism operated.
3. *Building* was reserved for when the participant was acting on an idea, when they were purposively constructing a possible solution.

The ability to differentiate ‘touching’ from ‘building’ was made possible by a standard video analysis methodology; to observe an activity that, in time, turned out to obviously be ‘building’, and then rewind and discern exactly when their activity transitioned from ‘touching’ in an exploratory way to purposeful ‘building’. Video allows for analysis of these moments, by reviewing what led to those moments.

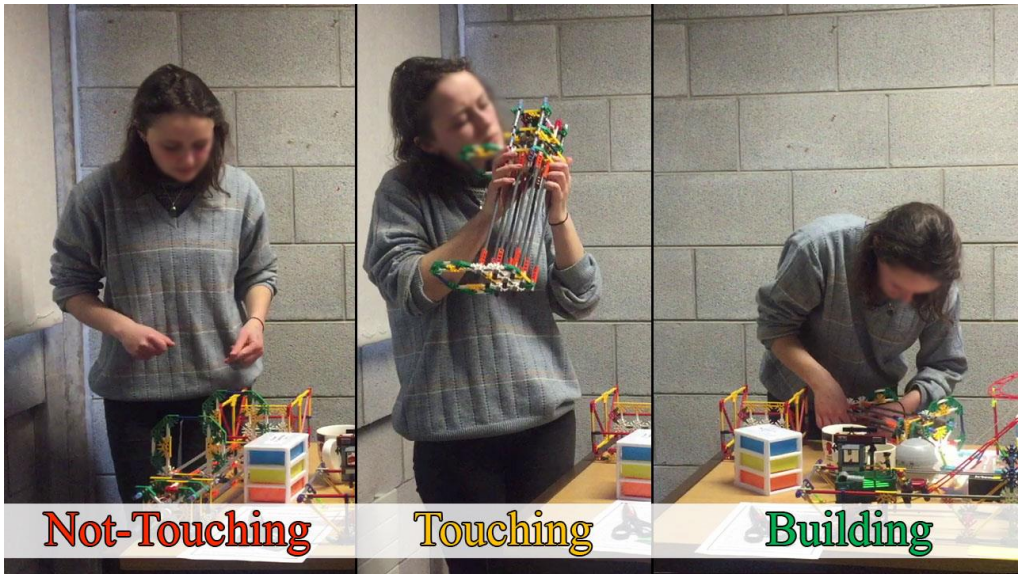


Figure 69 **Not-Touching; Touching; Building Sequence**

In Figure 69, see above, P19 is captured in all three activity categories.

To describe the results from this coding process, Figure 70, see below, represents the interactions of 12 participants (6 singles and 3 pairs) with a specific puzzle. It shows the temporal order of their ‘Not-Touching’, ‘Touching’, and ‘Building’ activities during successful puzzle-solving attempts. Colour-coding is: Red for Not-Touching; Amber for Touching; Green for Building.

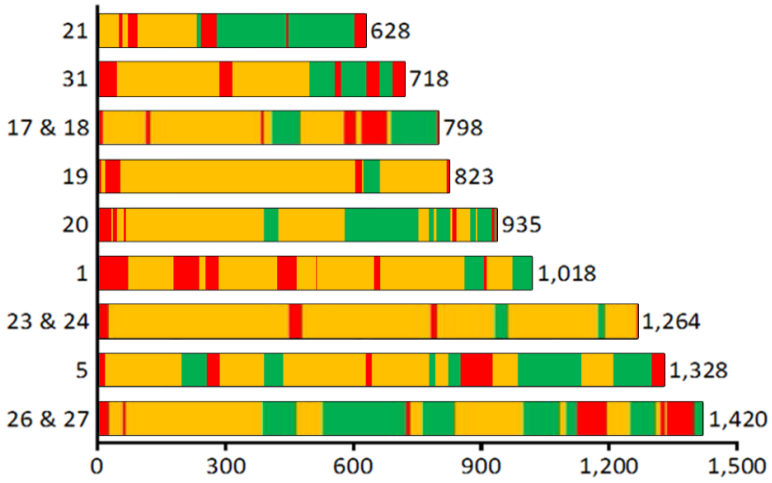


Figure 70 **Example of a Not-Touching, Touching & Building Timeline**

The y-axis is a list of those who completed the puzzle, fastest on top. Here, P21 was the fastest, completing in 628 seconds. The pairing of P26 & P27 completed it in 1420 seconds, the slowest of those who successfully completed it. The x-axis is the total time taken in seconds, with 300-second subdivisions (1500 seconds is equal to 25 minutes).

As a further example, Figure 71, see below, represents the interactions of the same 12 participants (6 singles and 3 pairs) with the same puzzle. It shows the total amounts, in seconds, of their 'Not-Touching', 'Touching', and 'Building' activities during successful puzzle-solving attempts, rather than the temporal order. The y-axis is, again, a list of those who completed the puzzle, fastest on top.

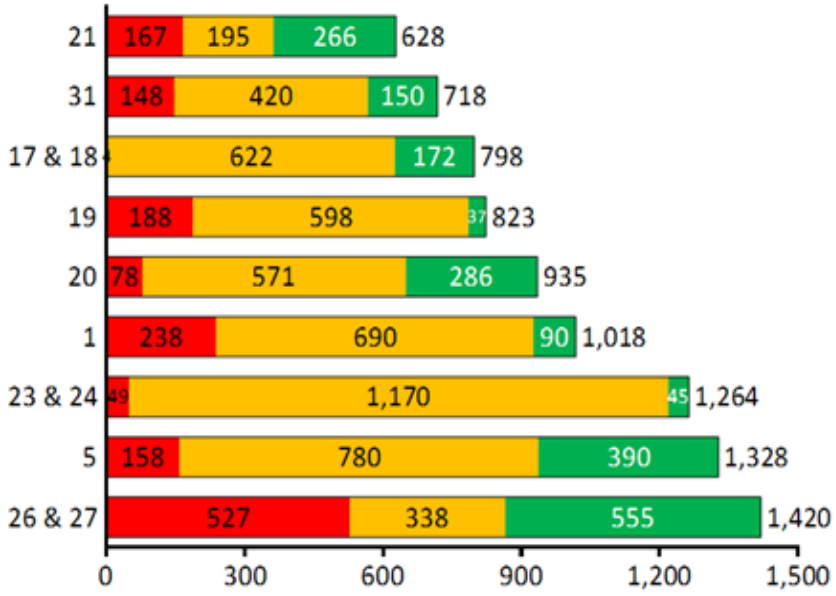


Figure 71 Example of Not-Touching, Touching & Building Activities

In this example, P21 spent 167 seconds 'Not-Touching', 195 seconds 'Touching' and 266 seconds 'Building'. No reference to their other choices is made here (e.g. clues accessed, the order of their attempts, etc.). The continually changing order of participants' activities, and their clue access, will be represented by individual timeline sheets in a complete form in the Appendices. Extracts from those timelines were presented individually, or as part of compilations (and/or within-text for commentary. No reference to their other choices is made here (e.g. clues accessed, the order of their attempts, etc.). The raw data (Excel) are presented in the appendices.

3.10 Clarification, Encouragement, and Silence (CES)

The social interactions between the Facilitator and/or their partner were classified into three categories. Relatedness is an important part of the educational process according to theory, hence the decision by the researcher to never leave the room and to actively play the role of Facilitator (Silva *et al.* 2014). After reviewing the videos, social interactions were categorized as: 'Clarification'; 'Encouragement'; and 'Silence'. Silence was judged as a worthwhile activity to analyse. While it literally described no interaction between the Facilitator and/or their partner, it was important to examine how relatedness or the lack thereof would be a factor.

1. *Clarification* signifies when the participant was either receiving information from me or exchanging information with their partner regarding the instructions or objectives.
2. *Encouragement* signifies when the participant was either receiving/giving emotional encouragement.
3. *Silence* signifies no interaction.

As an example, Figure 72 below, represents the interactions of 17 participants (7 singles & 5 pairs) with the Facilitator during their attempt with a specific puzzle. Colour-coding: Blue for Clarification; Green for Encouragement; and Grey for Silence.

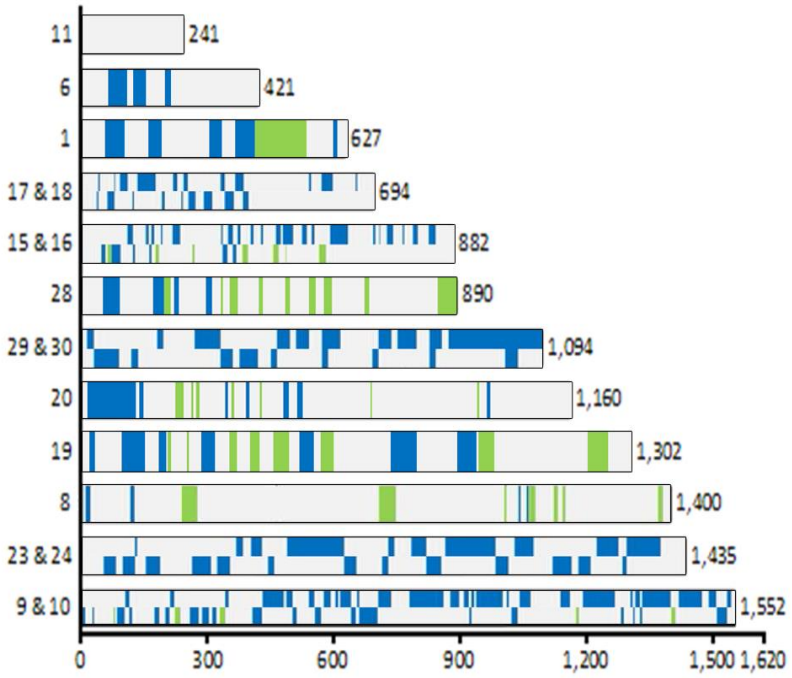


Figure 72 **Example of a Clarification, Encouragement & Silence Timeline**

This chart shows the temporal order of these interactions between ‘Clarification’, ‘Encouragement’, and ‘Silence’, during successful puzzle-solving attempts. For the pairs of participants, the top half of the bar is any interaction between the participants, and the lower half is any interaction between either of them or the Facilitator.

The y-axis is again a list of those who completed the puzzle, fastest on top. In this example, P11 was the fastest, completing in 241 seconds. The x-axis is the total time taken in seconds, with 300 second (5 minute) subdivisions (1620 seconds is equal to 27 minutes).

As a further example, see Figure 73 below, represents the same participants and their interactions with the Facilitator during their successful attempt with a specific puzzle. It shows the totals, in seconds, between ‘Silence’, ‘Clarification’, and ‘Encouragement’ during successful puzzle-solving attempts, with the paired participant’s interactions with each other visualised on the right-hand side of the bar. The y-axis is those who completed the puzzle, fastest on top.

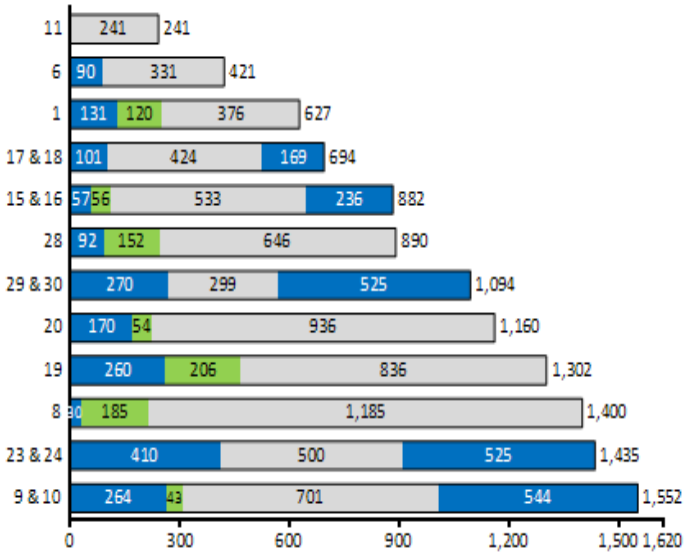


Figure 73 Example of Clarification, Encouragement & Silence Activities

In this example, P11 was the fastest, completing in 241 seconds, and did not interact with the Facilitator at any time, silently focused on the problem. P6 spent 90 seconds in total getting clarification, but no encouragement. P1 spent 131 seconds getting clarification, and 120 seconds getting encouragement. She was silent for the other 376 seconds. P17 & P18 spent 101 seconds asking for and getting clarification from the

Facilitator, 169 seconds getting/receiving clarification from each other, and spent 424 seconds in silence, not needing any encouragement. Clarification was usually given on request, and Encouragement was always initiated by the Facilitator, while avoiding giving them any information or hints (Savery 2015). This encouragement was given when they appeared stuck and was usually just a gentle reminder that they were free to move on to another puzzle or access a clue. In this case, P9 & P10 (slowest solve) spent 264 seconds asking for and getting clarification from the Facilitator, 544 seconds getting/receiving clarification from each other, and spent 701 seconds in silence, only getting encouragement from the Facilitator for 43 seconds, and never from each other.

The researcher was aware of the Hawthorne Effect[28], and leaving the room could have reduced this effect, but the participants would still have been intermittently aware of the cameras. However, testing how relationships affect design pedagogy was a significant element of this research (Deci and Ryan 2008).

This analysis of the video recordings of participant activity was a search for any patterns regarding performance and an attempt to understand the individual methods employed during those attempts. Specifically:

1. To try and understand how the physical nature of the puzzles affected their solving strategies and if there was a gauging of their 'competence'.
2. To examine how they related to the Facilitator and/or their partner (or not), and how these freedoms determined solving strategies, regarding 'relatedness'.
3. To consider what they did with their freedom to move at will from puzzle to puzzle, to access clues (or not), to act with 'agency'.

3.11 Researcher Bias & Lack of Reliability

As a safeguard against both the subjective nature of this type of analysis and the accompanying researcher bias, three associates were engaged for confirmation of the validity of this observation-based research method.

Two videos were chosen to test the robustness/objectivity of the researcher's analysis, those of Participants 19 and 21. P19 was reserved, quiet, and displayed a tendency to explore the problem-space by gently probing the puzzles until ready to quickly build

[28] The alteration of behaviour by the subjects of a study due to their awareness of being observed.

solutions. P21 was friendly, talkative, and displayed a tendency to explore the problem-space by dissembling the puzzles, alternating rapidly between exploring and building. Figure 74, see below, collates their activities. The x-axis displays the total times in seconds (2700 seconds = 45 minutes). For example, while both solved the Dalén Lamp, P19 took longer and spent much more of her time probing the puzzle, whereas P21's building activities were more speculative.

Colouring Coding: Red = Not-Touching; Amber =Touching; Green=Building.

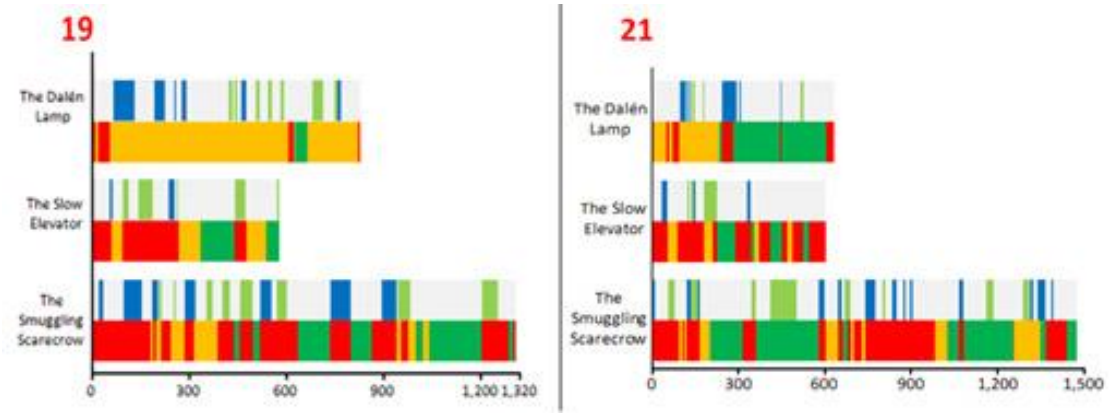


Figure 74 P19 and P21 comparison

All three individuals involved in the confirmation testing viewed the same two videos, but separately from each other. Tester 1 watched P19, then P21 (as had the researcher). Tester 2 & Tester 3 watched P21, then P19. The videos were 45 minutes long and were watched twice. The first run through was to ascertain the differences between the 'physical' activities (Not-Touching, Touching & Building). The second time was to ascertain the differences between the 'relatedness' activities (Clarification, Encouragement & Silence). Through experience, the researcher knew that the best process was to concentrate on the 'physical' and 'relatedness' activities separately. This requires two separate viewings, as trying to quantify the overlapping activities simultaneously is overwhelming. During both viewings, the testers had to 'rewind' dozens of times to review and confirm their timings.

The confirmation testers were (see Table 37, below):

ID	Relevant Skill Sets
Tester 1	Interaction Designer
Tester 2	Professional Educator: Technology Specialist
Tester 3	Data Analytics Expert

Table 37 Confirmation Testers

The testers were not asked to produce the codes for the activities. The researcher's coding process was explained to them to demonstrate the differences between the 'not-touching' of the puzzles, speculative 'touching' and the deliberate 'building' of a prospective solution. Recordings of several other participants were used for this explanation so that their approach to the videos of P19 and P21 would be uncontaminated.

'Not-Touching' is usually unambiguous, and the testers understood that confirming the researcher's findings for this category was the simpler part of this activity. They understood that the ambiguousness between 'touching' and 'building' was the key element to confirm (or not). If the testers' timings were similar, then they would be attributing the same observable activities to the same categories as the researcher. The timing was an instrument to see how appropriate the categories were.

Table 38, see below, presents both the researcher's original timings and the testers' deviations from those timings. All numerical values are in seconds. The testers' timings were averaged and the standard deviations from the means of the researcher's original timings were calculated. The larger figure on the left is the researcher's total for that activity. The smaller figure is the tester's deviation from that figure.

P19	**Not-Touching**	**Touching**	**Building**
Dalén Lamp	188: 4.3	598: 7.5	37: 3.6
Slow Elevator	331: 7.1	161: 6.8	83: 9.0
Smuggling Scarecrow	709: 4.5	197: 6.7	396: 2.8
P19	**Clarification**	**Encouragement**	**Silence**
Dalén Lamp	185: 2.7	94: 1.3	544: 2.1
Slow Elevator	26: 1.3	102: 2.0	447: 1.0
Smuggling Scarecrow	260: 1.2	206: 2.6	836: 2.2

P21	**Not-Touching**	**Touching**	**Building**
Dalén Lamp	167: 2.4	195: 10.4	266: 5.3
Slow Elevator	367: 3.6	101: 3.7	135: 6.4
Smuggling Scarecrow	617: 1.0	194: 1.5	658: 0.5
P21	**Clarification**	**Encouragement**	**Silence**
Dalén Lamp	86: 1.9	24: 1.4	518: 1.3
Slow Elevator	37: 3.8	59: 2.8	507: 1.9
Smuggling Scarecrow	184: 1.8	163: 4.3	1122: 4.1

Table 38 Confirmation Results

Observing the testers revealed that Tester 3 was physically slower to react to any changes in the observed behaviour of recorded participant activity, Tester 2 was much faster, and Tester 1 was between both extremes.

Regarding the Not-Touching, Touching & Building activities, the puzzles exerted an influence on the participant activity, and therefore the confirmation testing. The large size of the Slow Elevator puzzle and the many points of alteration meant that it was sometimes less clear whether a participant was 'touching' or 'building'. Also, participants tended to poke at this puzzle momentarily, so there was even an element of ambiguity between 'not-touching' and 'touching'.

There was a 2.1% deviation across the 'physical' activities (Not-Touching, Touching & Building), but only an average 1.2% deviation across the 'relatedness' activities (Clarification, Encouragement, Silence). This difference stresses the usefulness of the think-aloud method. As the 'relatedness' activities were almost always vocalised, there was less presumption needed for analysis. Regarding the physical activities, they were sometimes articulated (think-aloud) and sometimes were not. Therefore, stricter adherence to the think-aloud method would have resulted in more accurate findings, at least regarding what they were thinking. However, it would also have resulted in a setting that was more laboratory than realistic.

The close relationship between the original timings and the confirmation testers' timings demonstrated the validity of the categories. This providing encouragement to continue with the design of the exploration with these observable categories.

Other variables, such as 'Context Effect', where people's moods affect their performance, or 'Experimenter Effect', where the mood of the researcher, (or any other inconsistent behaviour), affects their performance were also important to consider. Regarding 'Context Effect', students are expected to turn up to lectures/labs/tutorials, and balance that with living a busy life. If ever implemented, any insights from this exploration would be within institutional structures. The researcher accepted that a context effect would be there, but in the same way that it would be in any future practical application. Regarding 'Experimenter Effect', this researcher did try to behave consistently with the students to reduce the effect. This matter of researcher bias is revisited in the Discussion chapter.

3.12 Individual Timelines

The timelines represent individual participant activity during the exploration. The x-axis represents the 45 minutes allotted for the exploration, see Figure 75, below.

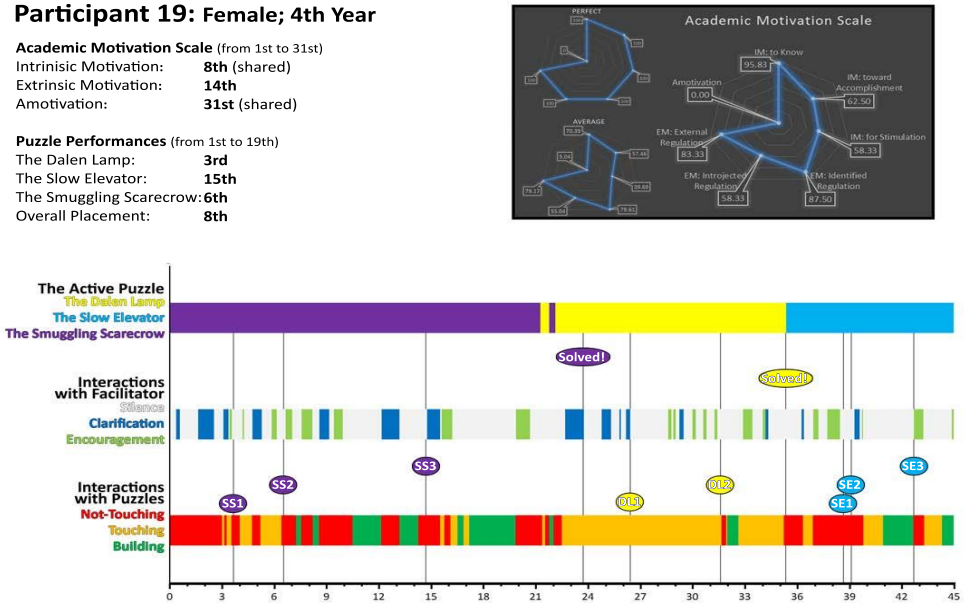


Figure 75 Example of an Individual Timeline

P19's timeline chart shows us that she started with The Smuggling Scarecrow, stayed with it until she completed it, and then moved to The Dalén Lamp, also staying with it until she solved it. She worked on The Slow Elevator until the time was up. A seeming anomaly is that she was working on The Dalén Lamp when she solved The Smuggling Scarecrow. She moved to The Dalén Lamp while her Scarecrow solution was 'in-action' (the Scarecrow takes 2 minutes to complete its motorised cycle).

Referring to 'Puzzle Performance', P19 had the 3rd fastest solve time for 'The Dalén Lamp', and 6th fastest solve time for 'The Smuggling Scarecrow'. Her 'Slow Elevator' ranking was ranked subjectively. Regarding the Academic Motivation Scale (AMS) rankings, many shared positions. For example, there were only 8 different scores for Amotivation from the 31 participants, with 18 scoring a perfect 0%. The AMS is discussed in detail in chapter 5 (section 5.5).

P19 chose to access 8 of the 9 clues, completing The Dalén Lamp without needing its 3rd clue. She spent less time building (19% of her time) then the average (27%). The full results of these tests are presented in the Appendices. The following section (3.13) details the reasoning behind the interview questions.

3.13 Semi-structured Interviews

The participants were emailed the questions ahead of time, so that they could have the opportunity to give considered responses (Bryman 2016). Also, the video recordings of the participants' puzzle-solving attempts were reviewed, and notes were taken of any events of interest. For example, if a participant became visibly frustrated or laughed aloud, then questions regarding these incidents were discussed during the interview. Otherwise, the questioning was consistent (with a single additional question for those that participated as pairs).

The questions were created following the guidelines:

1. Ask open-ended questions.
2. Avoid the use of leading questions.
3. Use terms that participants can understand.
4. Be mindful of the social or cultural contexts of the questions, etc.

The questions were as specific as possible, beginning with simpler topics and moving to those that were more complex in nature, beginning with warm-up questions, before moving on to more focused questions (Bryman 2016). The reasoning behind the questions was based on the measurable elements of both Self-Determined Learning (a general motivation theory) and pedagogical engagement theories.

Self-Determined Learning (SDL) theory states that when behaviour is self-determined, the regulatory process is choice. But when it is controlled (by others), then the regulatory process is either compliance or defiance. SDL is less concerned with how much motivation people have, and more about which type of motivation prevails in goal pursuit, a shift in focus from 'intrinsic vs. extrinsic motivation', from 'autonomous vs. controlled motivation' (Deci *et al.* 1991).

Pedagogic Engagement theory suggests that to measure engagement, four focal points are especially relevant: Behavioural, Emotional, Cognitive, Agentic (Veiga 2016).

The interviews all began with three warm-up questions (Bryman 2016) with all the questions listed in the following Tables 39-49.

1	How long have you been studying design?
2	What do you think defines a successful student?
3	What do you think defines a successful instructor?

Table 39 Warm-up Questions

Then a question that would explore 'Behavioural Engagement' and 'Relatedness'.

4	Why did you volunteer for this testing with me?

Table 40 Behavioural Question

Then, a pair of questions that attempted to delineate 'Cognitive' and 'Emotional' processes.

5	How do you think the physical nature of the puzzles affected your reasoning?
6	How do you think the physical nature of the puzzles affected your emotional engagement?

Table 41 Cognitive & Emotional Questions

The next group of questions were dependant on whether the interviewee participated on their own or with someone.

If they participated on their own, the questions were as follows:

7	How did "Working Alone" affect your thinking?
8	How did "Working Alone" affect how you felt?
9	Would you have preferred "Working in Pairs"? Why?

Table 42 Single Participant Questions

If they participated as a pair, the questions were as follows:

7	How did "Working in Pairs" affect your thinking?
8	How did "Working in Pairs" affect how you felt?
9	Would you have preferred "Working Alone"? Why?
9a	Were you comfortable with voicing your opinion?

Table 43 Paired Participant Questions

These three questions explored their Emotional Engagement.

10	How did you feel about dealing with physical puzzles in a learning environment?
11	How did you feel about your performance with the puzzles?
12	What would you have done differently?

Table 44 Emotional Engagement Question

This pair of questions explored, respectively, their Cognitive and Agentic Engagement.

13	How did the choice element, the ability to direct your learning, affect your thinking?
14	How did the choice element, the ability to direct your learning, affect how you felt?

Table 45 Cognitive & Agentic Engagement Question

This pair of questions explored their Cognitive and Emotional Engagement.

15	What was your favourite aspect of learning like this?
16	What was your least favourite aspect of learning like this?

Table 46 Cognitive & Emotional Question

These two questions also explored their Cognitive and Emotional Engagement.

17	Did you learn anything useful to you? What?
18	Did you learn anything that was interesting to you, and not just useful to know? What?

Table 47 Cognitive & Emotional Question

These two questions also explored their Cognitive and Emotional Engagement.

19	Do you think that your learning experience helped you to more fully understand Problem Reframing?
20	Do you care?

Table 48 Cognitive & Emotional Question

Finally, two general questions were asked, related to Cognitive Engagement, to allow for any general commentary/ranting.

21	Do you think that your learning experience helped you to more fully understand Design Thinking?
22	Why?

Table 49 Cognitive Engagement Question

3.14 Thematic Analysis of the Interviews

This would be primarily be ‘deductive TA’, which Braun & Clarke defined as a top-down approach (2018). The questions were based on a series of pedagogical motivation and engagement concepts. TA was used to both code and interpret the data. The analysis would also have elements of ‘inductive TA’, which Braun & Clarke defined as a bottom-up approach, where findings could be driven by what is in the data.

This deductive TA involved a six-phase approach:

1. Becoming familiar with the Data
2. Generating Initial Codes
3. Searching for Themes
4. Reviewing Potential Themes
5. Defining and Naming Themes
6. Producing the Report

Braun and Clark explain the process, illustrating with a data set to demonstrate the process and the form conclusions should take. They point out the common errors in poor TA: providing data extracts with little or no connection between the analysis and the purpose of the research itself, or just a summarizing of the data. They go further, by demonstrating good TA. Referring to their example data set, (a project dealing with sexual and gender identity in Higher Education), they explained how ‘Incidents of Homophobia’ would be a weak theme, as it only describes the different things participants reported in response to an interview question. But the theme of ‘There’s always that level of uncertainty: Compulsory heterosexuality at university’ was much stronger, because it captured something more complex about how homophobia and heterosexism shaped the participants’ university lives. The authors suggested thinking of themes as being like pieces of a jigsaw puzzle, to provide a meaningful picture of the data.

In the interests of privacy and discretion, some of the transcripts have some names excised (the original recordings are not edited). This is not referring to the participants themselves here, as they were always going to be anonymised. For all data records reproduced in this thesis, participants are referred to as P1, P23, etc. The excised names were those of teaching staff in UL, because of some bitter, angry remarks about their

negative role in a participant's educational experience. The participants were reassured that they must be fully honest, that not only were they 'allowed' to say they did not like this intervention, but that their honesty was needed for this research and was of great value. There was no expectation of such bitter anger about their other college experiences. As the identity of those lecturers was irrelevant to this research, their names were removed.

Regarding this analysis, the process began with a focus on the following questions:

1. How did they feel? Why?
2. Were they engaged? Why? How?
3. Did the physicality of the puzzles affect them? How? Why?
4. Did the SDL Theory prove valuable? If it did not, why not?

Because the researcher conducted the interviews and transcribed them all, there was a strong familiarity with the content before any analysis began. To ensure that nothing relevant would be missed, a succinct breakdown of SDL theory was printed out and visible while transcribing. In addition, the researcher was open to any emerging themes that were unexpected. To facilitate this, the interview questions became more open-ended as the interview progressed. The printed reference list of definitions was as follows:

Intrinsic Motivation

SDL-Competence (understanding how to attain various external and internal outcomes and being efficacious in performing the requisite actions)
SDL-Relatedness (developing secure and satisfying connections with others)
SDL-Autonomy (being self-initiating and self-regulating of one's own actions)

Extrinsic Motivation

External (a function of external contingencies of reward or punishment)
Introjection (taking in an external contingency, but not accepting it as their own)
Identification (accepting the importance of the behaviour for themselves and thus accepting it as their own)
Integration (succeeding at integrating an identification with other aspects of their true or integrated self)

Engagement Theory (ET)

ET-Behavioural (on-task attention, effort, persistence, lack of conduct problems)
ET-Emotional (presence of enthusiasm, absence of anger, anxiety, & boredom)
ET-Cognitive (use of strategic learning strategies, active self-regulation)
ET-Agentic (students' contribution into the flow of the instruction they receive)

Then, to aid the discovery of unexpected themes, responses were tagged (with a number) when a participant said anything that could be relevant in any way.

To serve as an example from the process, Questions 5 & 6 (immediately after the warm-up questions) attempted to delineate 'cognitive' and 'emotional' processes. Question 5 asked, "How do you think the physical nature of the puzzles affected your reasoning?" Their answers to this specific question were compiled into lists.

"**P1:** Holding the pieces in your hand helped…it helped me imagine how it could help and work…
P2: You can't test if you're just thinking about it. If it's something physical, you will have to go and "Can I do this?" and then go and do it, and then it doesn't work out.
P3: As opposed to just having to almost visualise it in your head. It's easier to like pick something up then just think about picking something up, if that makes sense.
P4: I'm very bad at visualizing things in my head…it would have been near impossible to do it in your head.
P9: The physical aspect took that away and you could see how things actually moved, you could see how things were actually put together instead of just assume that the pieces were working as they should, thinking in your head."

The above quotes (tagged 3, 8, 9, 11 & 12) all made the same point, that it was easier to simply look at it, instead of trying to visualise the problem. Every extracted quote was tagged with a unique number, in simple ascending order. The 1st quote was '1'; the next was tagged '2', the 15th quote, regardless of its content or category, was tagged '15', etc.

The responses to Q5 were tagged and then collated as seen below in Table 50.

Tag Number	Point made by Participant
3,8,9,11,12	It was easier to simply look at it, instead of trying to visualise the problem.
2,4,6,19,20,21,25,31,94	It was easier to simply change it, instead of trying to visualise changes.
7,9a,15,26,32,36,50	Tangibility/Interaction in general.
22,29,70,71,80,83	Helping to develop 'Cognitive Strategies'.
18,28b,28c,31a,31b,33,35,37, 38,39,40,41,42,48,49,51,79	Cognitive Feedback (building with the pieces provided guidance for their next step).
1,5,10,13,14,24,31,43,45,59	The pieces in my hand helped me think in a different way.

Table 50 An example from the TA process

This helped with the grouping of individual responses, to ensure that the points made were representative of the entire group, and not just made by a single individual. A short list was always made of the relevant theoretical elements, to maintain the link

between the theory and the written analysis. In Table 46's case, it was Constructionism and ET-Cognitive, where ET-Cognitive is the use of strategic learning strategies, active self-regulation.

The first two points ("It was easier to simply look at it, instead of trying to visualise the problem" & "It was easier to simply change it, instead of trying to visualise changes.") were often made in the same sentence. The full quotes were gathered, in an order that would lend itself to distilling the emerging data into a coherent narrative.

Question 6 asked "How do you think the physical nature of the puzzles affected your emotional engagement?" A similar process was followed when tagging and collating the responses to Q6, see Table 51 below.

52,53,54,55	A Love of Puzzles
75,93,95,103,104,109,110,111,112, 113,114,116,117,118,120,122	Pride/Challenge
64,65,89,102,105,106,119	Fun, Reward
23,56,57,58,60,61,62,63,66,67,68,73,74 ,76,78,82	Encouraged/Forced Participation
69,72,81	Determined to Solve
84,85,86,87,88,90,91,92,96.97,98,99,10 8	Determined to Learn
123,125,127	Learning about Themselves
17,124,126,128,129,130,131,132, 133,134,135,136,137,138,139,140, 141,144,145	Feeling self-doubt a lot
16,30,37a,46,47	Feedback Emotional
Criticism of other Teaching Methods	
146,152,158,159,160,161,163,165, 166	No passion
150,151,156,157,164,168	No clarity
148,149,153,155,167	Didn't learn anything from them
169	No emotional support

Table 51 Breakdown of TA: Emotional Engagement

After this process was completed with all quotes, the resulting tables were examined to develop coherent themes. For example, the unabridged document charting the development of the tentatively labelled theme 'Ease of Visualisation'[29] had quotes from 15 different participants.

[29] The unedited intermediate documents detailing all theme development are in Appendix C3.4.

Table 52, see below, lists the main points for this theme.

1	It was easier to simply look at it, instead of trying to visualise the problem.
2	It was easier to simply change it, instead of trying to imagine/visualise changes.
3	A love of puzzles.
4	Cognitive Strategies: Start with the easy puzzle, avoid the clues.
5	Tangibility/Interaction in general.
6	The puzzle gave feedback, good and bad, to guide the next step.
7	Not just by 'seeing', but the pieces 'in hand' helped them think in a different way.

Table 52 Breakdown of TA: Ease of Visualisation

This theme was eventually renamed "The Physical Feedback Loop". The relevant theoretical elements binding these quotes were Constructionism and ET-Cognitive.

A similar process was followed with the rest of the interview questions, eventually producing these additional four themes. Theme 2 became "Determined to solve, one step at a time". The relevant theoretical elements for these quotes were SDL-Competence, ET-Behavioural, and ET-Emotional. Theme 3 became "The Bitterness of Failure"; where the relevant theoretical elements were SDT-Competence, ET-Behavioural, and ET-Emotional. Theme 4 became "Sharing is one thing, winning is everything"; where the relevant theoretical elements were SDT-Relatedness, ET-Cognitive, and ET-Emotional. Theme 5 became "The Dilemma of Agency"; where the relevant theoretical elements were SDT-Autonomy and ET-Agentic.

3.15 Researcher Bias and Influence

This researcher made the decision to remain in the pedagogic environment for the duration, and to play the active role of Facilitator. This presents the obvious and persistent danger of 'researcher bias', affecting both the generation and the analysis of the data. Also, immediately before all of the pedagogic explorations, the researcher suggested to the participants that they should feel free to articulate what they were thinking, but did not insist that 'thinking-aloud' was an absolute requirement, and the researcher did not interrupt their activities by reminding them to 'think-aloud'. That decision was not taken lightly. Strict adherence to the thinking-aloud method would have resulted in more accurate findings, at least regarding what they were thinking. The objective was to simulate a class environment, to allow them to become engrossed in

their activity, rather than subjects in an experiment modifying their behaviour to facilitate ease of research.

Empirical studies, with an appropriately sized sample, are usually evaluated with concepts such as Internal Validity, Reliability, External Validity, and Generalizability. Internal Validity refers to a cause-effect relationship between variables, within a research setting (Brewer 2000). Reliability concerns the extent to which measurements of a concept are repeatable (Shadish *et al.* 2002). External Validity refers to the Generalizability of findings to target populations and settings (Drost 2011), with Generalizability being where we can generalize the findings from a sample to an entire population (Brewer 2000).

For a claim of validity, the choice of language used to describe the findings must be made carefully. Of relevance is the term 'Construct Validity', the extent to which a causal relationship can be generalized between a study's findings and the theoretical constructs they represent (Cook and Campbell 1979), in this case, Self-determined Learning and Pedagogic Engagement theory. In contrast to reliability, validity focuses on the relationships between indicators of theoretical concepts and theoretically relevant variables (Zeller and Carmines 1980).

Instead of *reliability*, a more appropriate term for evaluating this study is *dependability*; not whether the results of one study would be the same as a second or third study, but whether the results of a study are consistent with the data collected (Merriam 1995). The non-generalizability of findings is obviously a fatal flaw if the goals were to design an evidence-based intervention to solve a specific problem. But, as the purpose of this research was to test explanatory theory, then Construct Validity is an appropriate mechanism for rigorously exploring how Interaction Design students tacitly develop their comprehension of problem reframing, and how attempting to solve physical insight puzzles affects their engagement.

The researcher's active presence added a variable element, but the presence and activities of the researcher were necessary to explore 'relatedness' in action (Järvelä *et al.* 2016). If a participant came alone, then the most direct way of exploring this topic was for the researcher to play a role of some description. If they came with a partner, this role was still fulfilled by the researcher, but they were also free to interact with each other, another facet of relatedness. It is also true that a different researcher might

produce different results, and then draw different conclusions from those results. But relatedness is an important facet of the educational process, according to motivation theory, and must be further understood (Silva *et al.* 2014).

An appropriate framing of this argument is to replace *generalizability* with *transferability*, where a study's results can transfer to other situations with similar populations and characteristics (Lincoln & Guba 1986). As this study's real-world scenario would be a structured lesson as part of a formal design course, then the appropriate measure of rigour would be *ecological validity*: the exploration's relevance to the real world (Brewer 2000). Abstract concepts do not have a piecemeal correspondence with empirical indicators and can only be approximated by them. Here, with 'ecological validity' presented as an appropriate measure, then other researchers could consider this thesis' findings *transferable*, selectively applicable to their pedagogic research (Shadish *et al.* 2002). For studies involving human participants, validity is never the achievement of a single research project, but the produce of cumulative theory testing and application (Brewer 2000).

4 Results

4.1 Introduction

The results in this chapter are presented as follows:

1. A thematic analysis of the interviews with all 31 students, conducted in the days following their participation.
2. An empirical analysis of the physical activities of the participants during the event.
3. A comparison of individual scores from the Academic Motivation Scale (completed by every student immediately after their participation), with their activity during the event.

The thematic analysis, presented in section 4.2, is of the 31 interviews with all 31 participants. The 5 themes that emerged from the data are:

1. The Physical-Cognitive Feedback Loop
2. The Emotional Loop; determined to solve, one step at a time
3. The Bitterness of Failure
4. Sharing is one thing, winning is everything
5. The Emotional Dilemma of Agency

The statistical analysis of the video recordings, (section 4.3), presents the differences in activities between individuals across all three puzzles, with reference to the observable activities of 'Not-Touching', 'Touching', and 'Building' and their relatedness activities of 'Clarification', 'Encouragement', and 'Silence'.

As the Academic Motivation Scale is a reliable of indicator of motivation (Fairchild et al. 2005), and as the literature supports the position that there is a strong positive relationship between motivation, engagement and academic success (Fredricks et al. 2004; Wang et al. 2016), there was an expectation of distinct patterns between individual AMS scores and individual performances. These results are presented in section 4.4.

There were 25 separate ‘events’, with 19 individuals and 6 pairs participating. From those efforts, 6 individuals and 3 pairs solved The Dalén Lamp (a 39.1% success rate); 7 individuals and 5 pairs solved The Smuggling Scarecrow (a 48% success rate); and 12 individuals and 2 pairs solved The Slow Elevator (a 63.6% success rate). All these success rates refer to puzzles that were attempted (see Table 53 below).

How often was a puzzle solved (%)			
	Dalén Lamp	**Slow Elevator**	**Smuggling Scarecrow**
Singles	**33.3%**	**63.2%**	**36.8%**
Pairs	**60%**	**66.7%**	**83.3%**

Table 53 Puzzle Solve Rates

It is worth noting that only 3 of the 6 pairs attempted The Slow Elevator (2 of the 3 pairs that attempted it solved it), whereas all of the pairs attempted The Smuggling Scarecrow (5 of the 6 pairs that attempted it solved it), so both puzzles share the same amount of failed attempts (1 failure).

14 of the 19 single participants solved at least 1 puzzle; whereas all of the pairs solved at least 1, although no pairing solved all 3 puzzles, see Table 54 below.

How many puzzles did participants solve?				
	0 Puzzles	**1 Puzzle**	**2 Puzzles**	**3 Puzzles**
Singles	**5**	**5**	**7**	**2**
Pairs	**0**	**2**	**4**	**0**

Table 54 Puzzle Solve Amounts

4.2 The Thematic Analysis

What follows is the thematic analysis of 31 interviews, with all of the participants returning as promised for their follow-up interview. While 12 participants operated as 6 pairs during testing, all participants were interviewed individually.

4.2.1 Theme 1: The Physical-Cognitive Feedback Loop

"you could just try it, and then prove it in a second that it's wrong"

While reading the problem statements, participants limited their interactions with the puzzles to glances. Many participants were unhappy having to begin by reading something, revealing in interview that "sometimes you can feel like it's all words, all text, it can just take a lot of time to visualise it properly: P28".

Once they were finished reading, participants moved on to visually examining the puzzle. The physical nature of the mechanisms assisted everyone with comprehension of the problem statement, especially as all parts (both internal and external) were clearly visible. P3, risking stating the obvious, said "it was probably easier, because it's like 3D in front of you, as opposed to just having to…visualise it in your head". P18, someone who would "never pick up a manual", felt it was easier to "understand it straight off, as it was a physical thing that I could just go to and I could see every aspect", with many confessing they had experienced difficulties in the past with visualisation, when they didn't "have the physical thing in front of me. I can't actually see it, so it's kind of difficult to see the problem: P25".

This understanding of the initial problem state was deepened by their manipulation of any obviously adjustable parts of the puzzles, as "it was good to see the run-through at first, to see how it worked out: P28". It was simply easier to "see how things actually moved, you could see how things were actually put together instead of just assuming that the pieces were working as they should: P7". It also aided information retention, as "instead of trying to hold the information in…an imaginary state in your head, it's actually a physical state that you've seen, you've interacted with, and you can go back to that memory and be able to remember everything: P7".

Participants clearly realised that not only was the physicality of the puzzles helping them gain a fuller understanding of the problem that they had to solve, but it was also helping them with developing an accelerated understanding of how/what changes

should be made. This worked in both a general sense, where “sometimes you turn something upside down and you’re “oh, I get it now!”: P24”, and as a specific cognitive process as “it was literally changing the building of something, the actual structure, it would have been near impossible to do it in your head: P7”.

This included the abilities to touch the puzzle, and to walk around it to get a fresh perspective, “to interact with it on a one-to-one basis, rather than staring twenty feet away from a blackboard and trying to figure it out internally: P14”, and was “much better than just thinking about an equation: P9”. To be able to “think with your hands: P8” and interact with the puzzle was oddly relaxing and enjoyable, despite the self-imposed pressure many participants felt.

Participants commented that knowing there was an existing solution was encouraging. As it had been explained that these puzzles were representations of famous design thinking examples, participants “knew there was a solution, you just have to find a way, or an alternative way to do that: P24”. Interestingly, the physicality of the puzzle changed their perspective on general problem solving. P16, someone ordinarily lacking in confidence regarding her academic abilities, found herself “coming to terms with things quicker, and figuring out things quicker just because I could move them around…make it simple and build it back up.”

According to Pedagogic Engagement theory, a positive indicator of engagement is the conscious employment of cognitive strategies. For example, with The Smuggling Scarecrow puzzle, one of the clues revealed that gravity could play a part in a solution but did not elaborate on how this could be (all clues were initially concealed; see Theme 5). When participants simply moved the carriage up along the steep track, the movement of the barrels inside the carriage made it obvious exactly how gravity could now be leveraged to create a solution, with P18 recalling that she “wouldn't have understood that the barrels rolled, unless I’d seen it moving” with P2 stating that “the pulling of the train? It's something you can’t visualise, really.” It certainly made figuring out how to apply all available information into a possible solution “just easier: P30”, rather than “having to just thinking things out internally and try to picture stuff, you get to actually see the different components: P8”.

The physical structures that participants were interacting with were designed to funnel them toward possible solutions, as it would be asking a lot of inexperienced design

students to even attempt to replicate the important works of 3 famous designers in 45 minutes. Constructionism states that the comprehension of abstract concepts is accelerated by literal construction activities, and participants were now moving beyond an understanding of abstractions to creating solutions. The physical nature of the puzzles helped them to not only visualise the problem in a more useful way, but also to help them "see your actual solutions ahead of you, rather than trying to just internalise it: P8".

Any changes to the structures were like a reflexive conversation between the puzzle and the participant. The immediate feedback given by the puzzles, as each change was made, always informed their next step. They were "able to test it a lot quicker than…just thinking about it and writing it down: P23". Simply put, "rather than thinking 'will this work?' you can hold it up to the other objects and see 'no, this won't fit': P8", making "changes and see how they'd actually work, rather than just thinking of something and saying "oh, I think this would work", you can actually try it out: P30".

The ability to "physically manoeuvre things: P31" step-by-step naturally pushed participants toward a specific problem-solving cognitive strategy. As alterations to a K'Nex structure are incremental by nature, participants leveraged this to their advantage, even at the beginning of such attempts. "Once I knew I was getting somewhere with it, I was much more inclined to keep going because it was working somehow, I just needed to alter it a little bit: P31". This continued as participants progressed with every puzzle, as "each time I added another bit I could tell I was moving forward, another bit more, another bit more and then coming towards the end I was thinking "yeah that makes sense!" I knew that I was going to get it correct: P21".

Creative Design students are trained to think of repeated failure as a necessary, helpful part of the creative process. For the more experienced participants, this was their favourite part of the whole exploration, as they could see that, "ok that doesn't work, put it back together, try something else: P5", and that "you can just try it out, just try it out, like you think something and then you try it out. So, I just know that by trying out, you can eliminate it straight away, it's a lot quicker: P19". Participants didn't have to "waste time: P28" thinking about every possible variable beforehand, as "you can picture it in your head, but you can't always have every variable happen in your head so if you pull it up…will it be slow? Will it be fast? Will it rattle? Will things move?"

When you do things physically, you can see everything that is happening as you do it. So, you don't have to try and worry about what might happen: P21".

Many claimed that they preferred working with their hands whenever possible, rather than "learning off paper: P21". In addition, the physicality of simply holding the pieces, "being able to fiddle with them yourself: P21" helped participants to "imagine how it could help and work: P1". Some already knew this about themselves, that they were a better thinker when "touching stuff: P24", "especially when you have it in your hands, it's so much easier to think 'will this go in here? Will this happen? How will this work?': P21". Participants also were a "bit more adventurous: P25" than normal, even making speculative changes to "reveal the puzzle: P9". So, rather than consciously applying deductive logic and convergent thinking, it was their manipulation of the puzzles, and when they played around with the pieces, that helped participants to think divergently and move toward possible solutions, going as far as attempting to "answer a question that you don't know what the question is: P23".

These puzzles were representations of outstanding examples of problem reframing. When given in lectures, they are aspirational, something that a student may one day be able to equal. But this is always a passive experience, students being given the problem, then the context and thinking of the designer, and then the final solution all in the space of a few minutes. Here, they were 'constructing' their own knowledge by testing their own ideas, applying these to a new situation, and integrating the new knowledge gained with pre-existing intellectual constructs, for a deeper understanding.

This theme focussed on how a Constructionist perspective can be applied to design pedagogy, and examined how participants unconsciously employed strategic learning strategies, an indicator of positive engagement. The next theme explores how the behavioural and emotional engagement indicators were demonstrated, and also how 'competence', an important facet of Self-determined Learning theory, became relevant.

4.2.2 Theme 2: The Emotional Loop; determined to solve, one step at a time

"I wanted…to see them complete and know that I'd done them fully"

Participants were fully aware that by solving the puzzles, they would be replicating, as such, the 'design thinking' of a great designer and therefore have combined their training and natural abilities successfully, to become 'competent'. However, many of

the participants (13/31: 42%) admitted that one of their main reasons for volunteering was their love of puzzles, rather than a desire to improve their design skills.

For them, a puzzle is never just to pass the time. Rather, worthwhile puzzles are a challenge, a serious challenge to be overcome. P11 “had a bit of an emotional, competitive side going into it because I wanted to complete everything”. The choice of accessing clues during their activities was designed as a way of facilitating ‘Learner Agency’ (fully discussed in Theme 5). However, the participants uniformly interpreted accessing them as giving in, as “there was puzzles and I like a challenge. It wasn’t so much succeeding, as it is “rising to the challenge” that’s important to me: P21”. All participants wanted to solve all of the puzzles without using any of the clues; they all “wanted to figure out every possible way of doing it without looking at the clues first: P11”. Those that solved a puzzle without looking at its clues felt “a little bit better that I was actually able to figure it out by myself as well, without having to use the clues: P24”. Pride was a strong influence, with P21 pointing out that if he had “gotten the last one, The Lift [The Slow Elevator], or even the 2nd one [points at The Dalén Lamp] by accident, I would have I asked you if you could let me redo it again, because I would have hated the fact that I got it by accident, it's pointless”.

Those who did not solve all of the puzzles (29/31: 94%) expressed regret that they had mismanaged their time, only looking at the clues in a final act of desperation, and usually too late to make any use of the information. P28 expressed the common view that “the fact that I was just too stubborn [with] the 1st one, that I didn't want to look at the clues, and I wasn't paying attention to the time so I didn't realise how much time I was losing”.

After a disappointing effort, P3 said that if she had a do-over, she “probably would have checked the clues straight away.” Most participants would have still tried to solve without any help, but they would have accessed the clues earlier. When P5, (who solved 2/3 puzzles on her own), reflected on this, she admitted “it‘s a bit less exciting, less satisfactory at the end when ‘oh I’ve done it, but I used all the clues to help me out’”. Even so, when a participant solved at least 1 puzzle (26/31: 84%), regardless of clues accessed, there was still “the reward at the end when you solve, it is great because you actually get to see the finished structure: P8”. For example, “when we pushed down on The Lamp, and the light came on, ‘this is amazing!’: P23”.

This ‘emotional engagement’ factor, the presence of enthusiasm, was manifested as a sense of pride and achievement when participants solved a problem, and also when they almost solved one. The participants were especially invested as they were conscious that the puzzles were “related to real-life problems that happened, were solved by these people who won Nobel Prizes; that was my most interesting part...knowing that I solved a puzzle…it’s the achievement of it: P2”.

Encouragingly for any educator, participants were determined to learn from the process, naturally segueing from a strong desire to not just solve the puzzle but to learn from it, to understand the intended mastery goal. This is the ultimate objective for all educators but is a perspective that their students often do not share. This was exemplified by P29 commenting, “you're completely involved in it and it's up to you. It's not up to someone else to be able to teach you. It's up to you to learn from the puzzle.” A typical philosophical position was that you should “always have questions, always be learning...it's just boring otherwise: P12”, with participants’ natural curiosity in full effect.

They really enjoyed the challenge element, feeling that it would have been pointless to be just given the answers, even though that is what often happens in lectures. Success was perceived as, not simply solving the puzzle, but understanding what the underlying design concepts meant, what it was supposed to teach them, with P2 musing that “making mistakes are better than succeeding”. Having said that, they were pleased with themselves when they took a clearly positive step toward a solution, as it was “a challenge, it’s a puzzle. It kind of defeats the purpose if you’re taking out the answer as you're working on it…and then in that case it’s not a challenge, it’s not even a puzzle. It's pretty much back to rote learning: P21”.

They also felt it was especially memorable, as they were given to pondering afterwards over any interesting facets of their activities. This was obvious in interview, with their clear recollections of events and emotional responses to those specific “physical memories: P8” were still very strong. P14 said that he “really enjoyed it and came out of it then thinking about the problems after I left”.

This Behavioural Engagement, exemplified by on-task attention, effort and persistence was not just because it was a puzzle, or even because the puzzles represented a designer’s magnum opus. It was because of the “fact that it was physical, it was like a

challenge that was standing right in front of you: P21". As the puzzles were right in front of them, this ignited their competitive nature, (not in direct comparison with other people, just with themselves). The physical nature of the puzzles "forces you to actually think, whereas you could sit in a lecture hall and not take anything in. So that gets your brain going in a different way…you can watch TV but not actually be thinking. It's that same thing, but you're actually doing something, you actually have to think about it: P3". In a lecture, "you're just sitting there, looking at words, they kind of just go in one ear and out the other. Whereas, even if you don't intend it, you are naturally thinking if you're actually working with something: P28".

They felt that they had "no choice but to engage with the problem in the physical environment: P14" and as they went deeper into the 'design story', it wouldn't let them go emotionally, driving the compulsion to finish it, with P23 comparing the experience to the cinema, "like when you're watching a movie at home and you can get up and do whatever you want. If you're reading a book, you can just leave it. Compared to when you're in the cinema when you're sat down and staring at this thing, you're more emotionally attached to it".

While they did acknowledge that the physical activity of moving around the table of puzzles helped them stay alert, in comparison with just "sitting there falling asleep: P18", they were much more involved because of the puzzles being there in front of them, where they "had to see them complete: P6". Participants expressed a determination to solve, a 'need to get this done!': P3", that they had "to figure out what's right and wrong with it: P29".

They ruminated, not just over any new factual learning, but also how they felt about themselves, with P4 saying, "I learned quite a bit about myself, actually. About myself, it was interesting to see, looking back, how I handled myself…being beaten by pieces of plastic...I was very interested how I enjoyed it", with a more experienced designer reflecting that even though he had a solid understanding of design process "all of a sudden, I'm struggling. Very true, very telling: P12". Of special interest to educators was how many students shared the same emotional reaction when they came into the testing area, feeling that it was "overwhelming. When I came in first, I was 'that looks so hard, I dunno anything about K'Nex!': P5". During the testing, many participants faltered because of this lack of confidence, beginning from the default position of assuming they were not capable. This was more immediately obvious with the

participants that worked in pairs, as this second-guessing was vocalised. In the subsequent interviews, participants revealed that a lack of confidence in their abilities was a continuous hindrance to them, negatively affecting their thinking and motivation, feeling that they sound "stupid all the time: P18". P24 (working with P25 in a pair) articulated a correct solution during testing, yet didn't try to convince her partner to implement it until after accessing a clue that said the same thing, "Yeah, I was like 'it bends!' I completely second-guess myself; I don't know why…I think I just assumed I was wrong before I even tested it."

But, many of these same students also reported that the physicality of the puzzles combined with the incremental nature of solving them proved to be a distraction from themselves, especially from the "little voice in my head says 'you won't understand that!': P9". If it had been on paper, or mediated through any other traditional instructional medium, they would have felt "I don't understand", but seeing it "right there, you can change things, you can mess around with things, gets you in the flow, [if] this doesn't work, if I do this, this happens, if I take this, if I move this little thing, the whole thing is solved" I think it was really helpful, if that was wrote *[sic]* on a sheet of paper, I would be like "no, I can't solve it": P5".

They were able to concentrate because they were no longer seeing the whole puzzle, just the next step. They simply focused on that next step, and depending on the feedback from the puzzle, kept on that path or changed direction. This compartmentalising meant that they were focussed on the task at hand, on just getting to the next step and not how they would never be able to do this. "So, I think I've learned not to be put off. 'This isn't bigger than you, you can actually do these things!': P5" While this cognitive strategy was working well, it also was emotionally reassuring, as it was "rewarding to see it if you've done it correctly. I think it goes back to being able to apply it immediately there and then and being able to see the results of it. I won't ever forget this: P6".

Their desire to learn was demonstrated in their strategic approaches and a consistent reaction to a specific type of failure (see Theme 3). It was further manifested by participants' unprovoked criticisms of specific modules and lecturers that were, in their opinion, not good enough. Some general observations from two of the more experienced students were "there has been so many different modules which haven't been really related straight to design, which is…that's why I haven't thought I started

studying design until I went on Co-Op[30]: P1", with P3 wishing that "4 years ago, I started learning design like that [pointing at the puzzles]. I think I would be a lot more confident in it and probably think differently and think better if we had been taught things like this, the whole way through. But that just makes me sad about my course. I probably feel like I learned a bit more about design in that 45 minutes than I probably have done in most of my design modules, in terms of none of the rest of them have really changed the way I think about things".

Obviously, no one wants to listen to instructors who just "read off notes to you, especially in lectures: P8". These criticisms were motivated by a desire to learn, knowing that an instructor's lack of clarity is a lost opportunity. "I would say she does know her stuff, but because she can't communicate any of that properly, then it's pretty much useless to us: P21" and how some instructors were "brutal…absolutely no passion whatsoever! Loads of the lecturers we have are terrible because there's no excitement behind what they're talking about: P17". In addition, many participants explained that a lack of sympathy was an additional problem and how some instructors made them feel that they were stupid.

While it is reasonable to criticize this as a lack of a mature perspective on their part, it would seem that a positive relationship with an instructor is directly relevant to a student's enthusiasm, something the relevant literature bears out (Shevlin *et al.* 2000). In this case, many of the participants (18/31: 58%), when asked why they volunteered, specifically stated that liking the researcher was their main/only reason.

This theme explored how the physical nature of the puzzles triggered an emotional reaction in participants. Many were puzzle enthusiasts and considered a worthwhile puzzle to be a personal challenge. Learning something worthwhile, becoming 'competent' at the same time, added to what was a uniformly enjoyable experience. The incremental nature of interacting with the puzzles created a natural, positive distraction, where the participants normally hampered by self-doubt were always focussed on the next step of the puzzle and not how they felt about themselves. However, there was a common emotional reaction to a specific type of failure revealed during the reflective interviews. This will be discussed in the next theme.

[30] Co-Op is UL's 8-month industry work-placement between 2nd & 3rd Year.

4.2.3 Theme 3: The Bitterness of Failure

"It's been giving me nightmares"

Participants revealed that their initial objective was always to solve all three puzzles, an objective that was reviewed as the rather constrained time frame advanced. Once they began the puzzle-solving process, participants were absorbed in their own step-by-step thought processes, being genuinely excited and feeling "a sense of an adrenaline rush, of using my brain in a different way: P4", even as the time-pressure became more intense. "With the time frame, you're kind of just rushed into thinking fast, thinking straight to a solution: P24". P7's opinion was that "when you're having a bit more fun, you think more creatively, so I definitely think it frees up a lot of your thought, and it means you're not under as much stress then you otherwise would be". While their attention was obviously focussed on working toward successful completions, they were consciously avoiding any help unless they really needed it. See Table 54 below for a summary of the puzzle-solves.

Amount of Successful Puzzle Completions =	**0/3**	**1/3**	**2/3**	**3/3**
19 Individual Participants	5	5	7	2
12 Participants (6 Pairs)	0	1	5	0

Table 55 Completion Rates for all Participants

On reflection, participants felt that they should have accessed the clues earlier, that they had made a misjudgement, as P28 put it, "the fact that I was just too stubborn in the 1st one that I didn't want to look at the clues and I wasn't paying attention to the time so I didn't realise how much time I was losing". Similar regret was expressed by P3; "I probably would have checked the clues straight away. Just to have them and get going faster". Reflecting on their individual performance, they were very pleased with themselves when they had solved a puzzle, momentarily at least. When they narrowly failed to complete a puzzle, perhaps concocting a correct solution but failing to implement it, they were still satisfied with how much they learned from the experience, with P19 admitting that "I was happy with it, even the last one [The Slow Elevator], even though I did it the wrong way round, I kinda had the right idea…nearly". As it was a learning environment, it was considered a noble defeat, reinforcing SDL's theory that the development of "competence" is much desired by students.

If participants got nowhere with a puzzle and felt that the revealed solution would have evaded them no matter how much time they had, they had much the same reaction, an easy acceptance of a reasonable failure. But there was always an underlying sadness and disappointment "because when I arrived here, I think 'ok, we're going to solve them all', but, then again...it was great. It was very interesting. I liked it: P19". When asked how they felt in general about their performance, while some responded with "ok-ish" and "it was fine", responses were typically "should've done better", "over-thinking it", "disappointed", "so bad", "let down myself", "stupid", "it was frustrating", "inadequate", "terrible", "annoyed", "lacklustre!" with some using expletives, even though many of those quoted solved 2/3 puzzles.

More to the point, many participants delivered an emotionally laden, detailed recounting of a specific type of error in interview, that of fixation. These fixation errors were when a participant made a presumption (that was false) and so all subsequent steps pushed them away from a solution. While having speculative ideas and acting on them to see if they are a good idea is a part of the design process, here fixation specifically means that a participant took a false step when they should have known better, when there was enough information clearly available to them beforehand to know this. For example, P17 and partner P18 narrowly failed to complete all 3 puzzles, successfully moving to the final puzzle (The Slow Elevator) with 15 minutes to spare. This puzzle was (statistically) the easiest, so a quick finish was expected (by the researcher). However, despite fully grasping the problem statement and articulating a correct solution in minutes, they eventually ran out of time. Their fixation error was as follows. They correctly removed a thin K'Nex piece because it was too short. If they had replaced it with a thin, long piece (of which there were several within easy reach) they would have finished straight away. They instead searched for, and replaced it with, a thick K'Nex of the correct length (which needed them to also search for and insert a size adaptor). This was a strategy that would never work. Despite the physical feedback from their decision indicating what the problem was, they continued on the same path, continually exchanging different lengths of the thicker K'Nex pieces until the time ran out. When the solution was demonstrated straight after their time was up (on request from them), they were extremely angry with themselves. In interview, P18 said "the thicker ones that weren't going to work compared with the lighter ones, and I should

have made that connection, that maybe if it was a little bit lighter, it would help it slow down a bit more."

When participants were recounting these types of fixation errors, they were visibly angry as they re-lived them. Even those who objectively did well were still very upset. P11, (who solved 2 of the puzzles and was very close to solving all 3), recounted, with eyes blazing, that "it's been giving me nightmares! Yeah, yeah, still annoying me." They all understood that they had gotten "stuck on a certain way of thinking: P18". Any recounting of their successes, or when they were reminded of how clever they had been, provoked a far less intense emotional reaction. P24, minutes away from solving all 3, bitterly recounted that "I am disappointed in myself that I didn't just try that stupid bendy stick in there when I said it, and then I feel like we would have had more time to get all of them done." As she was by now aware, 8 minutes passed between her articulating a problem-solving idea and finally acting on it, but only after reading the same idea in a clue. See Figure 76 below, for both moments.

Figure 76 P24, 8 minutes apart

It was interesting that participants' reaction to solving, narrowly failing, or completely failing were similar, in terms of intensity at least. While apparently intensely engaged during the event, afterwards they were either moderately happy or a little disappointed when they succeeded or failed, respectively. In addition, any disappointment was moderated as they felt they had learned something useful from the experience. Their anger was reserved for when they had fixated on an element that was then shown to be the reason that they did not complete the puzzle. Then there was a bitterness, a feeling

that they had let themselves down badly, a feeling of how could they have been "so stupid!: P21".

Before participants began, it was explained to them that everything about their puzzle-solving attempts was a pedagogical exploration; to examine if/how any findings could be applied as a method of explaining somewhat abstract concepts such as "reframing a problem-statement". While the presence of negative emotions such as anger and anxiety would ordinarily be considered indicators of a lack of emotional engagement, it is argued that, in this case, these were very strong, positive indicators of 'behavioural engagement', of intense on-task attention, effort and persistence. This specific type of anger was the strongest indication of their personal investment in the puzzles. Their personal pride, where they felt they were rising to a challenge, was always a strong factor in their personal engagement during their efforts. On personal reflection, when they felt that they let themselves down, then the recounting of it was with an intense bitterness.

4.2.4 Theme 4: Sharing is one thing, winning is everything

"I think she slowed me down"

The pedagogic literature on Relatedness, SDL Theory included, states that it is an important requirement for students as they find their place in their educational environment. A successful facilitation of relatedness (the development of secure and satisfying connections with others) creates an emotionally supportive environment that is conducive to learning. However, when any general Motivation Theory (SDL) is applied to specific circumstances, it either becomes a fully successful Theory of Engagement, or elements of it fail in the testing environment.

Participants were told that they could either come in pairs or on their own. All those who came as a pair came with a friend. In addition, all participants who arrived on their own revealed that they had deliberately done so, rather than not having any friends available. For example, all three Industrial Design students lived together, worked together, shared the same schedule, and are very close friends who socialise together, yet all three chose to arrive separately. But, when asked directly about how they felt about this decision after the fact, there was a common, qualified regret.

For those who came alone, the single reason for any regret about their decision was that "pairs probably would have been easier: P3", easier as "I could have bounced ideas off someone, and if someone had said something, it might have triggered for me: P3". Conversely, this same person also said that if only she had had more time, then she would still "have preferred working on my own". Those who came in pairs felt it was a good decision. However, it was always good for the same reason, for increased efficiency rather than emotional support or fellowship. While those who arrived with their best friend admitted that "it was a lot better to work in pairs: P24", they admitted it was better because "there is another person here to collaborate, to think aloud along with me, so that we might come up with the idea faster than if I'm alone: P20". All such comments, where some regretted coming alone or were glad they had brought a friend, were always framed as comments on efficiency. Everybody was conscious of the fact that a pair would have "double the brainpower: P19".

Expressions regarding the positive nature of sharing the experience were conspicuous by their absence. The closest to this was a singular comment, when P30 said she held back sometimes, as she wanted her partner to "have a go as well". However, even though P30 was sincere in her comments, she also complained that her partner had "slowed me down". Conversely, the identical opinion was shared by her companion (P29), with both feeling they were being hindered by the other!

Even though everyone understood that two minds are theoretically stronger than one, most of those who arrived alone did not regret that decision at all. Many desired the freedom to do things their own way, as it was "empowering: P2". They enjoyed the challenge, admitting that it was liberating not "having to consider other people's opinions or views on the problems that I was able to focus on my own trying to fix it: P18". They were even imagining the frustrations of having to deal with another person as something stressful, or with everything taking so much longer that "it never would have been done on time: P8". When you are on your own, "it's only your own brain has to understand it: P20". They had come on their own because "afterwards, it's a sense of achievement because I done it, rather than me and someone else: P31".

For much the same reasons, regret was offered by some of those who came as pairs, with P29 suggesting that "I think if I worked on it by myself, I might have been a little bit better at it, because you don't always have to consult with somebody else "what you

think about it?" I know teamwork is obviously a good thing, but sometimes working on your own is also good because you learn from it".

Self-doubt manifested in both single and paired participants, as they were unsure of what exactly awaited them in the testing environment, and participants admitted to the specific fear of appearing stupid in front of others. They avoided that awkwardness by coming on their own, and it remained a constant worry for some of those who came as a pair. Those who came on their own were glad to be free of judgement, with P25 feeling "a lot more free because I also didn't have another person doing the puzzles with me and judging me and my suggestions so I kind of felt free to do whatever I wanted". P1, who liked making a private "mess in my head", complained of this constant voice in her head telling her she's wrong, telling her "it's definitely not just that!"

Like P1, P25 felt that "if I was in a pair, I would have been less inclined to try out ideas in case they were wrong, cos there would have been someone else there saying 'that's wrong!'" Those who came as a pair were constantly juggling both the positive ("they help you and encourage you that you are doing it the right way: P24") and the negative aspects of working in a team ("I feel fear that maybe she judge me, that 'oh, I would have done better if this girl wasn't with me!'": P10).

In general, it is reasonable to assume that positive emotional support is always important, as it was here. But in this specific educational exploration, where the participant genuinely cared about how well they did, 'relatedness' was reduced to something to be leveraged to gain an advantage in the moment, a cognitive support and not an emotional one.

Participants who arrived on their own did admit to wishing for a companion, but only to improve their chances of success. Those who arrived with a friend quickly reduced that friend to a cognitive aid, more and more so as they became engrossed in the puzzles. Regarding their relationship with their institution (rather than their peers), 18 of the 31 participants explicitly stated their reason for volunteering was because they liked the researcher. 3 others said that a friend had encouraged them to volunteer after they had participated. The remaining volunteers said they either liked puzzles and/or research. 3 of the participants were Industrial Design students that the researcher had never met and admitted they had only participated because their housemate was a student of mine that "made them"! The entire cohort of their Industrial Design course were emailed by

their course director asking them to volunteer but not a single student responded, except for the 3 that participated.

This theme demonstrates that relatedness/fellowship between participants, while not unappreciated, was only important when directly providing help solving the puzzles rather than a sharing of the experience. They certainly appreciated the emotional support. It was always, however, a distant second to the individual getting help to solve the puzzles. In this exploration at least, 'emotional relatedness' had an inverse relationship to 'cognitive engagement'.

4.2.5 Theme 5: The Emotional Dilemma of Agency

"It was like giving in"

Both SDL and Pedagogic Engagement Theory assert that agency/autonomy would improve educational engagement. Choice is one of the joys of personal life, but in an educational environment, instructors create syllabus content, with the only choices available to students are a list of elective modules and/or assignment topics. It is speculated that a student with more agency/autonomy is a student that is more engaged (Reeve and Tseng 2011).

Participants were specifically informed at the beginning that they could start with whichever puzzle they wanted, and that they did not have to complete any puzzle to qualify to move on to another. This choice, a freedom to strategize as they willed, was welcomed for a variety of reasons. One reason was that it simply eased pressure and frustration levels, with P1 saying, "I felt that I'm not under such pressure to finish one and then move on. Everything was really good; I didn't feel frustrated if I had to stick with one and finish it all the way through." This freedom of choice was relaxing, as being able to move between puzzles reduced their stress levels, and it increased their feeling of control. They knew that they could "roam about: P5", that they "didn't have to solve that to go on to the next one: P18".

Strategies varied between participants, with some choosing to focus on one puzzle at a time (until they solved it or got stuck), with others casually flitting between them, with P3 feeling that "if you move onto the next one, you can take your mind off it for a second, and think about something in a different way and it will trigger something about this one over here", essentially a strategy of attempting all three puzzles at once.

Reaction to this freedom of movement and strategy was positive, but with one common exception. The singular complaint from participants was that this freedom, in practical terms, equated to a lack of guidance. A few felt that the choice of where to begin was somewhat intimidating; with P29 acknowledging that "you have the freedom to pick what you like. But, at the same time, there's just too many options, where do you start? What do you choose?" But they all wanted to do well, to solve all three puzzles, so they wanted to know the correct order to attempt the puzzles if there was one.

As revealed in interview, participants differed in tactics, most trying to get "the easy ones out of the way: P17", but with some wanting to "get the hard one done first: P14", rather than just picking one at random. But they had to guess at each puzzle's objective difficulty. Many started with The Dalén Lamp as they felt it might be the easiest, even though it turned out to be the most difficult puzzle, the opposite of what most wanted. Being given the information regarding relative difficulty at the start, (but without being told what they should do with that information), would have been uniformly appreciated.

Participants were fully conscious that the hidden clues represented the ability to control how much help they were receiving, meaning they could control how challenging each puzzle was, that they could make a "'contribution into the flow of the instruction they receive" (Reeve and Tseng 2011, p.2). They all wanted to solve the puzzles without using any clues. This was a matter of pride, a case of rising to the challenge, with P21 reflecting that "it's a challenge, it's a puzzle. It kind of defeats the purpose if you're taking out the answer as you're working on it…in that case it's not a challenge, it's not even a puzzle." Using the clues was perceived as giving in, a lessening of the challenge, even carrying an element of failure.

Many participants referred to the clues as "cheats: P2", as cheating even though they "know it's not, but that's how I feel about it: P3" While participants knew that the clues "were kind of a backup: P6", when they did use them it was with a heavy heart, "a sense of defeatism because you feel like 'I shouldn't need these!' but you do and therefore I'm a failure: P4". Of course, the structure of all three puzzles was always directly assisting them, funnelling them in the correct direction. But, as they were told that they would not *have* to access the hints to solve the puzzles, then that automatically became the challenge set before them, to solve without any hints. P14 said that he "wanted to challenge myself and see if I could get it without any assistance". Accessing a clue,

“admitting you need help: P24” was only acceptable when you were stuck, only if “I can’t figure this out, I have to look at it!: P24”.

Participants contributed “into the flow of the instruction they receive” by accessing (or not) the clues; knowingly reducing the difficulty of the puzzles and thereby changing the learning experience. In the end, all the participants that failed to solve all three puzzles regretted not using the clues earlier. On reflection, they would have preferred to complete all three puzzles, even if it did mean they were “giving in” and “cheating”. They misjudged the timing by looking at the clues much too late to put the information to any use to formulate a solution and build it, with P14 admitting that “…for The Scarecrow, I absolutely dived into the clues because I was under time pressure…the choice element added to the...took away an awful lot of pressure, I think. I know I keep saying ‘pressure’ even though there’s no pressure involved in it, but...” P28, who really did not want to access any clues, accessed them when she suddenly “realised how little time I had”.

Introducing autonomy into a structured educational experience is difficult. However, in this case, the pressurised environment (albeit self-inflicted pressure because of personal pride) was relieved by autonomy, as the participants felt more relaxed than they would have been if operating under stricter rules. It was a positive experience having the freedom to strategize as they pleased, it was relaxing, and it increased their conscious feeling of control. But their decision to consistently access the clues too late for them to be of much use was because of their pride. They cared about their pride more than solving while engaged in the exploration, but afterwards they regretted that decision. It was always an emotional reaction, and never an intellectual one.

4.3 The Statistical Analysis

The design of this pedagogic environment had an objective of generating data in categories that were aligned with the SDL theoretical framework, to make sense of what was uncovered[31]. The Interaction Design student cohort (+3 from Industrial Design) was all volunteers; a mixture of those who wanted to be helpful and those who liked

[31] I express my appreciation for Professor Alan Dix’s Guide to Statistics for HCI, found at: https://alandix.com/statistics/course/

puzzles, often a combination of both. They were all design students with representative levels of the different stages of experience and training.

The research hypotheses were to quantify any differences in physical behaviour and 'relatedness' behaviour as each participant moved between the different puzzles. In more formal terms, the research hypotheses were:

1. $H_{0:}$ There are no statistically significant variances between 'Not-Touching', 'Touching' and 'Building'.
   $H_{A:}$ There are statistically significant variances between 'Not-Touching', 'Touching' and 'Building.

2. $H_{0:}$ There are no statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.
   $H_{A:}$ There are statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.

As the intent of this numerical analysis of their activities was to quantify any patterns in behaviour and to then extract meaning, ANOVA was chosen as the test instrument. ANOVA is a one-way analysis of variance used to determine whether there are any statistically significant differences between the means of three or more independent groups, as opposed to a t-test, which is a method that determines whether just two populations are statistically different from each other (McHugh 2011).

Specifically, ANOVA tests the null hypothesis ($H_{0)}$. However, if the test reveals statistical significantly differences, the one-way ANOVA cannot indicate *which* specific groups were different from each other, only that at least two groups were. To determine which specific groups differed from each other, a post-hoc test is needed. The raw data from the analysis is presented in Appendix A. A summary of the results is presented now, in the sections 4.3.1-4.3.3.

4.3.1 The Dalén Lamp Results

Figure 77, below, reproduces the activity details of those that solved The Dalén Lamp.
RED: Not-Touching; AMBER: Touching; GREEN: Building

BLUE: Clarification; Lt.GREEN: Encouragement; GREY: Silence

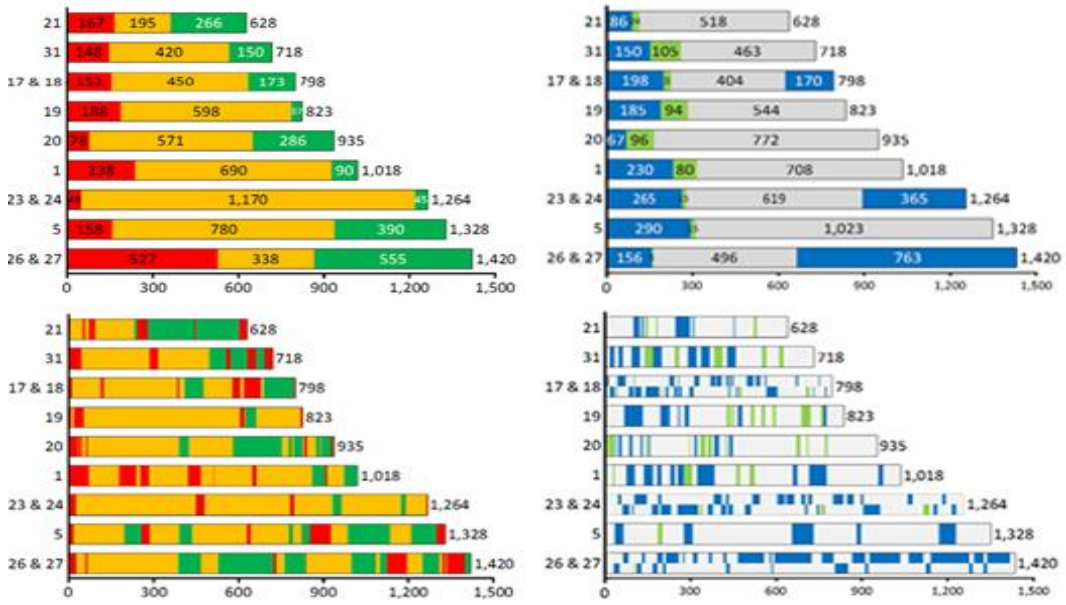


Figure 77 The Dalén Lamp Compilation

An examination of the Not-Touching, Touching, and Building visualisations revealed that there was a statistically significant difference between the three groups as determined by a one-way ANOVA ($F(2,24) = 11.139$, $p = .000378$); Table 56, below.

Patterns in 'Not-Touching', 'Touching' and 'Building' for The Dalén Lamp	
Between all 3 groups	$(F(2,24) = 11.139, p = 0.000378)$
Between Not-Touching & Touching	$(F(1,16) = 15.966, p = 0.001041)$
Between Touching & Building	$(F(1,16) = 11.795, p = 0.0003404)$
Between Not-Touching & Building	$(F(1,16) = 0.399, \ p = 0.53643)$

Table 56 Patterns in NtTB: The Dalén Lamp

An examination of the Clarification, Encouragement, and Silence visualisations also did not reveal a consistent pattern; Table 57, below.

Patterns in 'Clarification', 'Encouragement' and 'Silence' for The Dalén Lamp	
Between all 3 groups	$(F(2,24) = 18.328, p = 1.47^{-5})$
Between Clarification & Encouragement	$(F(1,16) = 8.366, \ p = 0.010605)$
Between Encouragement & Silence	$(F(1,16) = 74.274, p = 2.08^{-7})$
Between Clarification & Silence	$(F(1,16) = 6.586, \ p = 0.0207)$

Table 57 Patterns in CES: The Dalén Lamp

4.3.2 The Slow Elevator Results

Figure 78, see below, reproduces the details of those that solved The Slow Elevator.
RED: Not-Touching; AMBER: Touching; GREEN: Building
BLUE: Clarification; Lt.GREEN: Encouragement; GREY: Silence

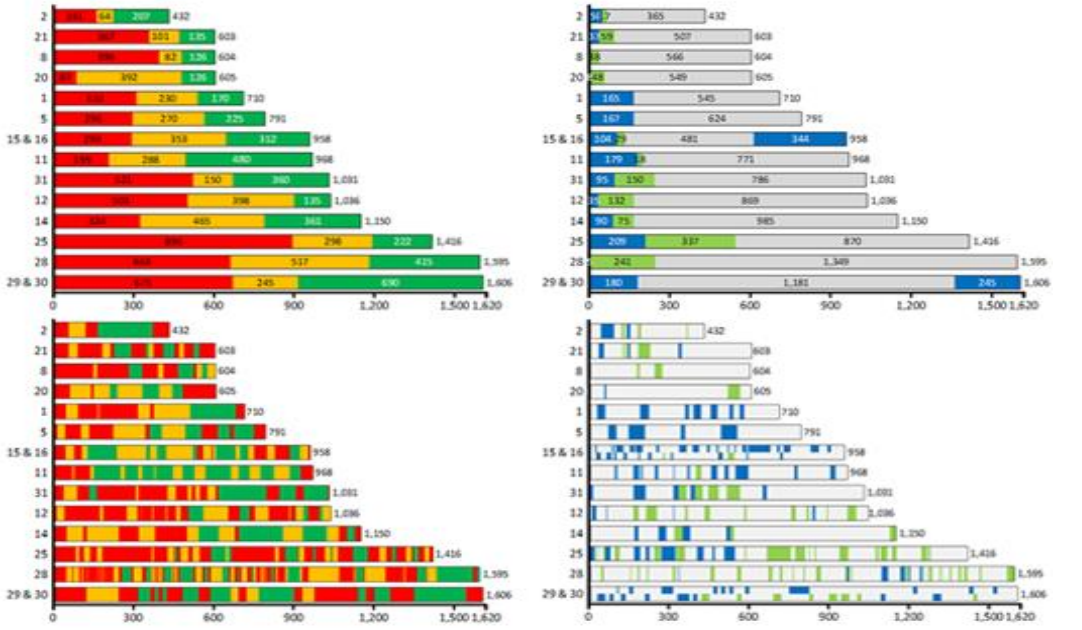


Figure 78 The Slow Elevator Compilation

A statistical examination of the Not-Touching, Touching, and Building visualisation did reveal some consistency in performance, see Table 58, below.

Patterns in 'Not-Touching', 'Touching' and 'Building' for The Slow Elevator	
Between all 3 groups	(F(1,39) = 2.34, p = 0.1099)

Table 58 Patterns in NtTB: for The Slow Elevator

An examination of the Clarification, Encouragement, and Silence visualisation didn't reveal a pattern between the Encouragement' and 'Silence' grouping and the 'Clarification' and 'Silence' grouping. There was no statistically significant difference between the 'Clarification' and 'Engagement' grouping (see Table 59, below).

Patterns in 'Clarification', 'Encouragement' and 'Silence' for The Slow Elevator	
Between all 3 groups	(F(2,39) = 51.332, p = 1.19^{-11})
Between Clarification & Encouragement	(F(1,16) = 1.354, p = 0.255)
Between Encouragement & Silence	(F(1,26) = 68.462, p = 9.35^{-9})
Between Clarification & Silence	(F(1,26) = 51.448, p = 1.29^{-7})

Table 59 Patterns in CES: for The Slow Elevator

4.3.3 The Smuggling Scarecrow Results

Figure 79, see below, reproduces the details of those that solved The Slow Elevator.

RED: Not-Touching; AMBER: Touching; GREEN: Building

BLUE: Clarification; Lt.GREEN: Encouragement; GREY: Silence

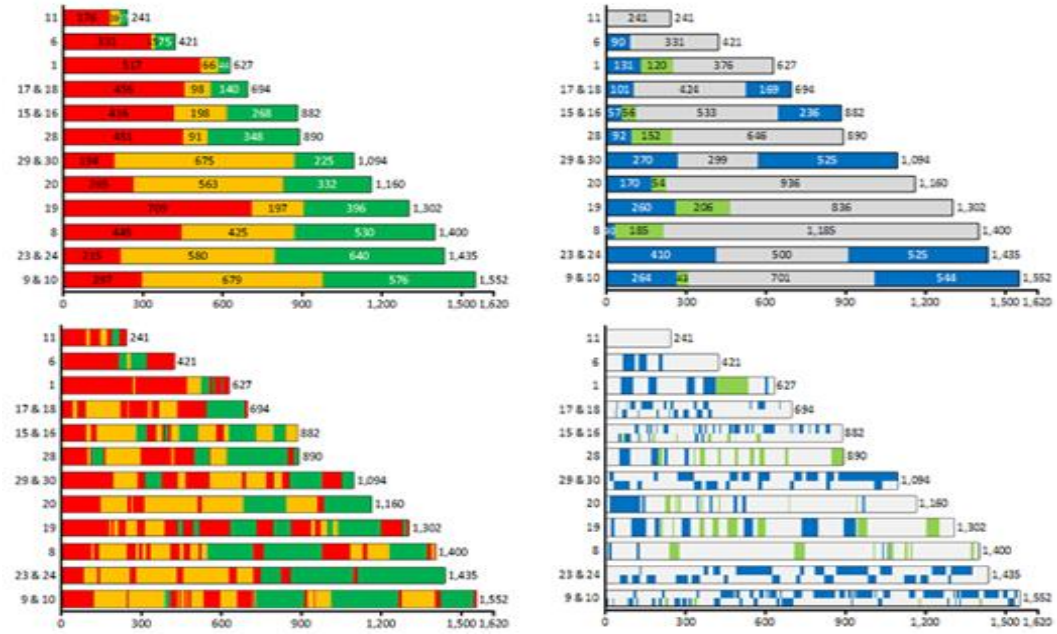


Figure 79 The Smuggling Scarecrow Compilation

A statistical examination of the Not-Touching, Touching, and Building visualisation did reveal some consistency in performance pattern, see Table 60, below.

'Not-Touching', 'Touching' and 'Building' for The Smuggling Scarecrow	
Between all 3 groups	(F(2,33) = 0.449, p = 0.642)

Table 60 Patterns in NtTB: for The Smuggling Scarecrow

A post-hoc examination of the Clarification, Encouragement, and Silence visualisation did not reveal a pattern between groupings, see Table 61, below.

Patterns in 'Clarification', 'Encouragement' and 'Silence' for The Smuggling Scarecrow	
Between all 3 groups	(F(2,33) = 13.07, p = 6.59^{-5})
Between Clarification & Encouragement	(F(1,22) = 6.729, p = 0.0165)
Between Encouragement & Silence	(F(1,22) = 36.079, p = 4.8^{-6})
Between Clarification & Silence	(F(1,22) = 5.215, p = 0.032)

Table 61 Patterns in CES: for The Smuggling Scarecrow

4.4 Participant Performances & The AMS

The AMS results for The Dalén Lamp are presented in Figure 80, see below. The y-axis is the scores for Intrinsic & Extrinsic Motivation, expressed as a %. The x-axis represents the solvers, from the fastest (P21), all the way to P27, the slowest solve.

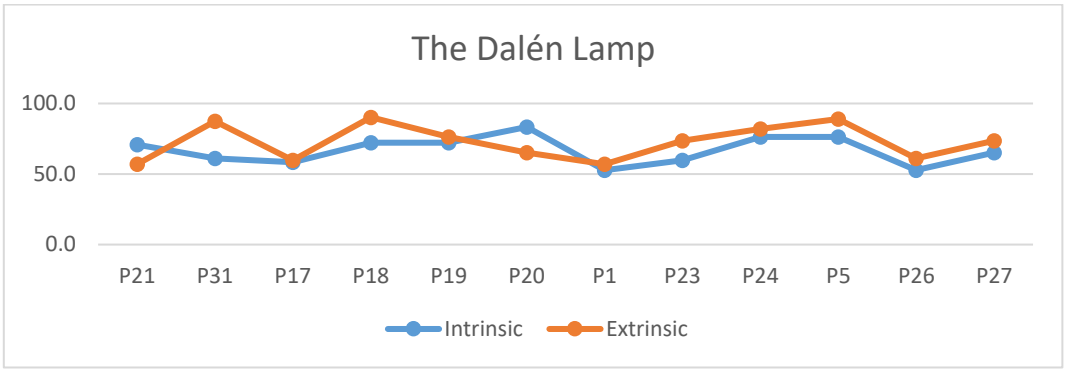


Figure 80 The Dalén Lamp AMS vs. Speed Chart

The results for The Slow Elevator are presented in Figure 81, below.

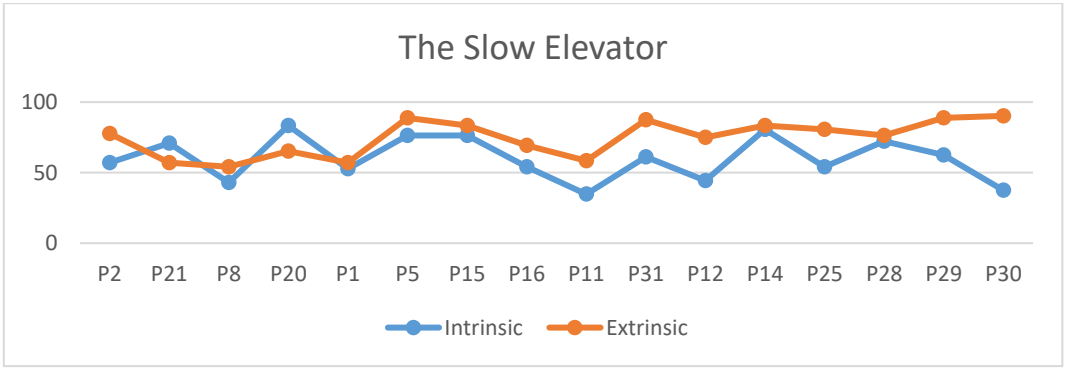


Figure 81 The Slow Elevator AMS vs. Speed Chart

The results for The Smuggling Scarecrow are presented in Figure 82, below.

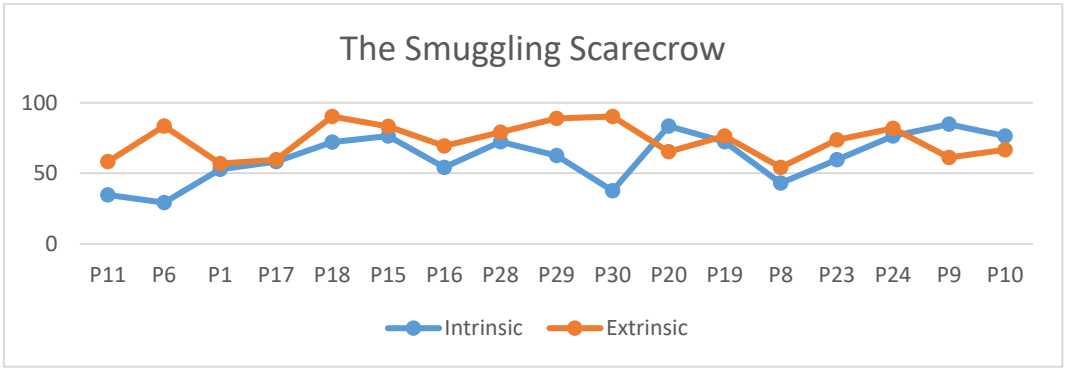


Figure 82 The Smuggling Scarecrow AMS vs. Speed Chart

Figure 83, below, displays the mean AMS scores from all the participants.

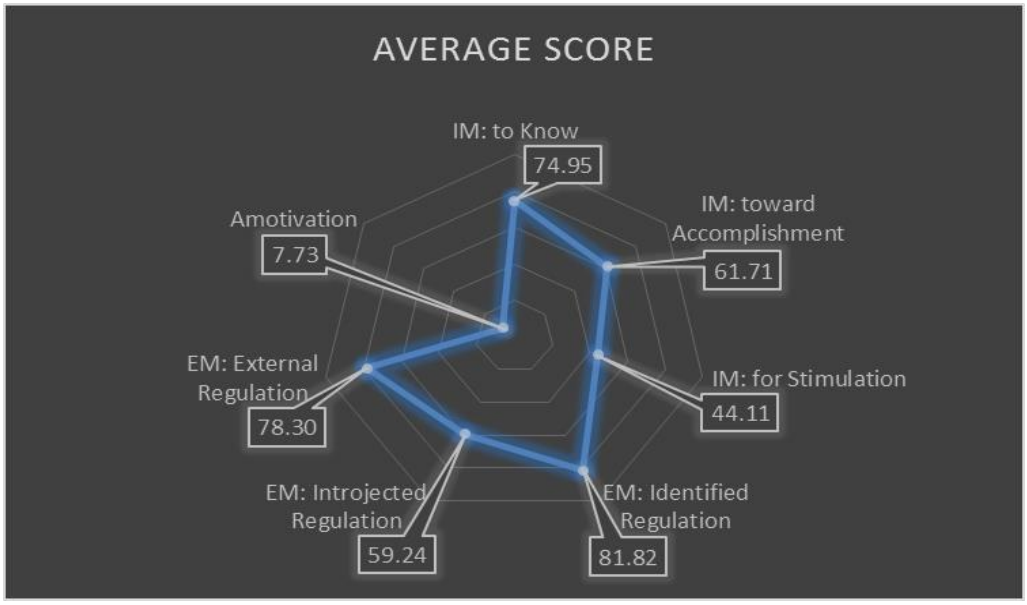


Figure 83 An Average AMS

Figure 84, see below, represents a compilation of the best individual scores posted by the participants. It is worth emphasising that, in pedagogical application, SDL theory is concerned with helping a student progress through the degrees of Extrinsic Motivation toward Intrinsic Motivation (Deci *et al.* 1991).

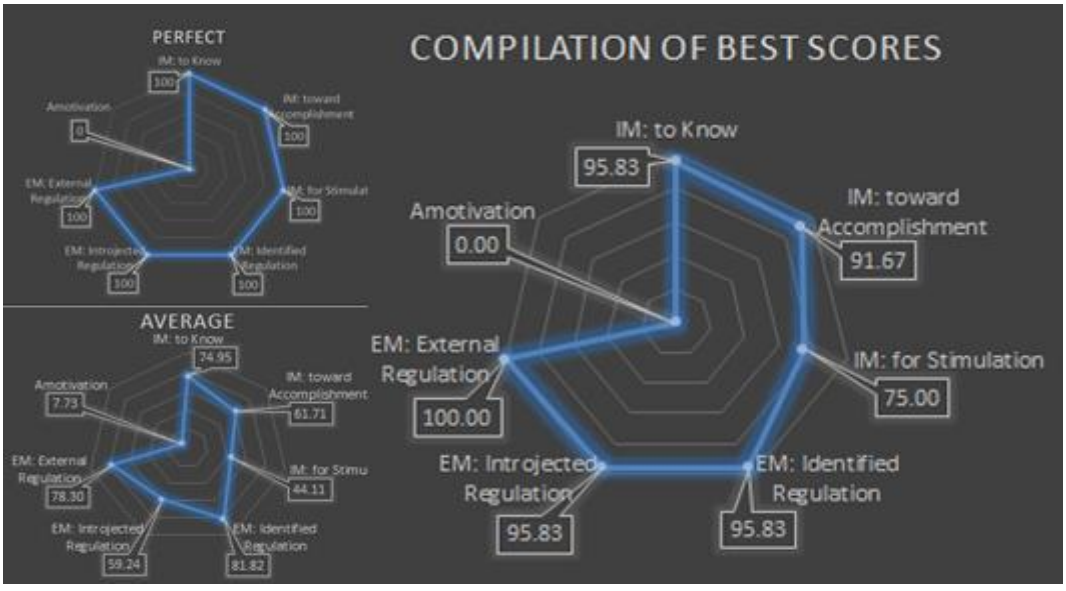


Figure 84 An AMS Compilation

The results presented in this chapter were the thematic analysis of the interviews, the empirical analysis of participant activity recorded during the event, and a comparison of individual scores from the AMS and those individual's solving performance.

The results were a mixture of qualitative and quantitative methods, but all referred to the same pedagogical experience. The thematic analysis focused on how participants felt about both the experience and about themselves. The statistical analysis focused on how their physical behaviour changed with each puzzle, but their relatedness behaviours were consistent across the puzzles.

The Academic Motivation Scale was presented very briefly in this chapter and is discussed in more detail, with the insights gained from these results, in Chapter 5.

5 Discussion

5.1 Introduction

This chapter brings together the contributions this study has made to the field of Interaction Design pedagogy. The objective of this research was to explore and contribute to the development of a method for teaching Interaction Design, specifically tacitly teaching ill-defined problem solving to Interaction Design students, and to answer these two research questions:

Q1. Under what conditions can an Interaction Design student tacitly develop their comprehension of the abstract design concept of problem reframing?

Q2. What is it about attempting to solve physical insight puzzles that affects the engagement of an Interaction Design student in their design studies?

The research findings, as they relate to the research questions, are discussed in the next two sections (5.2-5.3).

5.2 Problem Reframing

To become an Interaction Designer, a design student must learn to think like an Interaction Designer. For such designers, the ability to 'problem solve' is important, and as design problems often involve 'problem reframing'. According to Schön (1983), the ability to reframe the situation is essential to design thinking, through the application of both divergent and convergent thinking processes (Rowe 1987; Lawson 1990).

The literature suggested that even when an individual knows ahead of time that they are facing an insight problem *and* they understand the solving process, there is still a natural inclination toward beginning with analytical, reproductive thinking. Then, if the problem resists analytic thinking, then you must become unreasonable in a smart way (Perkins 2001). This setting allowed for investigating this notion, that creative thinking in Interaction Design is a path from Convergent Thinking to Divergent Thinking (to get over an impasse by reframing the problem), then immediately back to Convergent Thinking to realise a final solution (Weisberg 2015). But, the literature also supports

the position that these classifications may be too strict a demarcation, and that Design Thinking cannot solely defined by the Divergent Thinking process, and may have more of a relationship with deductive reasoning and Convergent Thinking than previously believed (Bowden 2005).

This delineation of thinking processes has proved its usefulness, even if it may eventually be replaced by a more holistic approach. Both cognitive constructs, (Convergent and Divergent), are useful ways of thinking about thinking, directly influencing the development of many successful teaching methodologies (Guilford 1967; Lawson 2006; Savery 2015). An outstanding application of Convergent Thinking in education is Problem-based Learning in Medical Training. This is Constructivist learning in a pure form, as constructivist learning *always* requires a puzzlement to be solved, to be contextualised and then assimilated into existing knowledge. PBL in Medical Training obviously focuses on presenting opportunities for medical students to solve well-defined problems through deductive reasoning (Savery and Duffy 1995).

This simulated environment presented opportunities for Interaction Design students to tacitly develop their design thinking by learning how to resolve ill-defined problems; adopt solution-focussing strategies; employ abductive thinking and reasoning; and use non-verbal media (Cross 2006). Interaction Design students could gain this design knowledge by gaining practical experience in design thinking, using this 'pedagogical bridge' to help them experience design thinking even if they were inexperienced as designers. Design experience is invaluable, as experts can leverage their superior depth of knowledge and experience to reach conclusions faster, focussing on solution-generation, while novices keep their focus on problem-analysis for longer (Cross 2004; Kruger and Cross 2006).

The physicality of the puzzles helped the participants to engage cognitively, because it was a challenge standing right in front them. Seeing and touching the puzzle helped them to quickly gain a fuller understanding of the problem that they had to solve, but it also assisted them with developing an accelerated understanding of how/what changes should be made, how the problem should be reframed. The physical nature of the puzzles helped them to not only visualise the problem in a more useful way, but also to help them visualise the possible solutions ahead, rather than trying to reason with their mind alone. Not only this, but the physicality of simply holding the pieces, of being able to "fiddle with them", helped participants to imagine how the puzzle could help

them to figure out what to do next. The participants developed the cognitive strategy of leveraging the immediate feedback from the K'Nex puzzles. If their idea seemed to be going in the right direction, they continued. If not, they used that feedback to alter their strategy in a specific direction. When they did this, there was no negative emotional ramification regarding that failure. A false step was no longer a negative step. They naturally perceived that their understanding of their mistake had now become guidance, reflexively giving themselves a hint as to the right direction (Schön 2017). Instead of contemplating how they should be reframing the problem, they just did it; they intuitively reframed without being fully conscious of the process.

The freedom to explore and the lack of negative consequences enabled them to fail, to fail better. Their fuller understanding of 'failing better' is another example of their gaining of tacit knowledge through this experience. Just as sketching is exploratory, what Schön called a 'reflective conversation', the participants responded to the backtalk of their own puzzle adjustments with confidence. When they realised that they were taking a step in the wrong direction, they were happy because this feedback always told them why their idea was wrong, and they now had a strong indicator of what to do next. This experience was one of the highlights for many of the participants, as they were vaguely aware of the concepts of 'reflexion' and 'failing better' but admitted that only now did they understand them. This experience had been 'active learning' and not just a passive experience.

Many participants admitted to a default position of doubting their own abilities. This hindrance was relieved by the incremental nature of the puzzles, where they automatically focussed on the next step only. An unintended consequence was that, in interview, many students reported that the physicality of the puzzles (combined with the incremental nature of solving them) proved to be a distraction from themselves, especially from the little voice in their head that says 'you won't understand that!' Where seeing it "right there, you can change things, you can mess around with things, gets you in the flow, [if] this doesn't work, if I do this, this happens, if I take this, if I move this little thing, the whole thing is solved".

This is reminiscent of the aphorism 'a journey of a thousand miles begins with a single step'. While many admitted to being overwhelmed by the apparent complexity of the puzzles at first glance, once they began on their exploratory journey, the puzzles' physical nature naturally pushed them into a one-step-at-a-time cognitive strategy. It is

acknowledged in pedagogical engagement theory that a lack of self-esteem will affect motivation and engagement (Linnenbrink and Pintrich 2003). The physical nature of the puzzles seemed to help some participants deal with their self-esteem issues by providing a welcome educational distraction, albeit by happy accident as this was not foreseen as a potential outcome by the researcher.

Another interesting factor was that some solvers' strategies seemed to be dictated by their skill level with K'Nex. Some participants created rather complex solutions with moving parts. While this was unnecessary, their solutions still counted as they met the design brief and solved the problem. However, their expert skill-levels with K'Nex were generally a hindrance. Some elaborate mechanisms worked with The Dalén Lamp, but not at all for The Smuggling Scarecrow. In interview, they admitted that the reason they did this because they could, rather than it being a considered approach regarding the correct strategy.

This pedagogical exploration became more useful than it was designed to be. By design, it allowed for learning about 'problem reframing', but it also allowed for learning about 'fixation'. Their learning first-hand about fixation was an unintended consequence. While some participants understood the concept, when participants committed an act of fixation, they were uniformly angry, feeling they had let really themselves down. P11, (who solved 2 of the puzzles and was very close to solving all 3), recounted, with eyes blazing, that "it's been giving me nightmares!" They all fully understood that they had gotten "stuck on a certain way of thinking". Any recounting of their successes provoked a far less intense emotional reaction.

They were experiencing reframing and fixation, not just learning about it. Rearticulating their reactions during the interviews became a part of the pedagogical intervention, where they combine their experience, their tacit learning with their academic learning. Even when a team of medical trainees fail to solve a problem set by their instructor, they still learn from the process. They learn how to deal with each other in a team, how to develop their reasoning abilities, how to focus and apply their knowledge base in an environment that mimics their future professional practice. The analysis of failure can be a profound learning experience, often providing more insight than a success. Interaction Design students were now doing the same, but in a designerly way.

Both problem reframing and fixation are important for any design pedagogical practice, as a full grasp of both concepts is necessary for a designer's cognitive development. This simulated environment created a setting where Interaction Design students could be introduced to the concepts with only a few words, but then more fully understand them by applying them, tacitly mimicking their future professional practice. Schön's concept of 'reflection-on-action' describes this, where new 'knowing-in-action' can be tacitly developed *after* practice (Munby 1989).

5.3 Pedagogic Engagement

According to Self-determined Learning Theory, motivation is measured across three areas: competence, relatedness, and autonomy. Indicators of this motivation are respectively: becoming effective in performance; developing relationships and feeling understood and cared for; being self-initiating and self-regulating of one's own actions, being the originator of one's behaviours (Deci *et al.* 1991). The analysis of their performances and subsequent interviews was intended to:

1. Understand how the physical nature of the puzzles affected their solving strategies and if there had been a gauging of their 'competence'.
2. Examine how they 'related' to the researcher playing the role of Facilitator, and/or their partner (or not), and how this affected their solving strategies.
3. Consider how their freedom to move at will from puzzle to puzzle, to access clues (or not), to act with 'agency' affected their experience.

According to Pedagogic Engagement Theory, engagement is measured across four areas: Behavioural, Cognitive, Emotional, and Agentic. A "socio-behavioural dimension" should also be included (Fredricks *et al.* 2016). Indicators of this engagement are respectively: on-task attention, effort, and persistence; the employment of cognitive strategies; the presence of enthusiasm; the reaction to having choice and control. In interview, the participants described 'behavioural engagement', as the physical nature of the puzzles forced them "to actually think, whereas you could sit in a lecture hall and not take anything in. So that gets your brain going in a different way…you can watch TV but not actually be thinking. It's that same thing, but you're actually doing something, you actually have to think about it". They explained that

reading about a situation to understand its meaning was OK, but if they then had to act on that information, they now had to try and visualise, to imagine, to guess what they should do next. They felt that 'thinking with your hands' was so much easier, so much better.

This was a consequence-free environment, regarding grades at least. In the Design Studio, students can express and explore ideas, generate and evaluate alternatives, but the process of design critiques often puts students in a 'sink or swim' position, with a strong potential for souring the relationship between student and instructor (Akin 2002). Just as a badly handled design studio can have a negative motivational effect on students, the freedom in this pedagogic space had a positive motivational effect.

Being engaged in a cerebral fashion is one thing; being emotionally engaged is another. Here, students genuinely cared about doing well; they cared about becoming more 'competent'. They felt that the puzzles were a challenge. Many participants (13/31: 42%) freely admitted that one of their main reasons for volunteering was their love of puzzles, volunteering with an optimistic outlook, hoping for a serious challenge. Some participants, after enjoying their experience, told their peers that it was well worth doing (but never giving away any other information). This was another expression of the importance of 'relatedness'.

When they solved a puzzle there was a sense of reward, by getting to see the finished structure. They felt that they were completely involved, not just in the challenge but in a pedagogical environment, as they knew they were learning something genuinely useful. In interview, many found it easy to recount specific thoughts and feelings when prompted about their activities. They felt they now had physical memories, easy to recollect. It should be remarked upon that this exploration was unique in their university experience, and therefore memorable. If any lecturer had presented information to them from a handstand position, they would also have remembered the event but not necessarily much about the content of that lecture. Even so, it was interesting that, during individual interviews, participants could easily recount exact details about their performance, even though their event was weeks in the past by then.

Participants felt they learned a lot about reframing regardless of whether they solved a puzzle or failed in the attempt. P19, (one of the more successful participants, solving

2/3), admitting that “I was happy with [pointing at The Slow Elevator], even though I did it the wrong way round, I kinda had the right idea…nearly”. It was a noble defeat.

This exploration generally provoked three emotional reactions in participants.

1. Being quite pleased with themselves if they solved a puzzle.
2. Being moderately displeased if they failed but had made a good effort.
3. Being angry if they committed what were classed as fixation errors.

The emotional engagement factor, ‘the presence of enthusiasm’, was manifested in a sense of pride and achievement when participants solved a problem. Even when they almost solved one but did not, they were quite pleased with themselves. The physical nature of the puzzles provoked an emotional reaction. It encouraged, even impelled, them to focus on solving the puzzles. They were prideful in their efforts to solve, but they also expressed a strong interest in the learning outcomes. Their focussed learning was because of their cognitive and emotional engagement. P21 said, “it’s not so much succeeding, as it is rising to the challenge”. The gamification elements meant that the puzzles became a personal challenge. Participants acknowledged that being given the answer would have been a return to rote learning. P11 had “an emotional, competitive side going into it because I wanted to complete everything”. If a student solved a puzzle, they had proof they were competent. If they failed, they were given to mulling over exactly why they failed, with the desire to do better next time, to improve in their competency. If they failed because of fixation, they were even more motivated for the next time.

P3 thought about her difficult experience with the K’Nex puzzles long and hard afterwards, and in interview declared that if she had a do-over, she “would have checked the clues straight away. Just to have them and get going faster”. That she was still thinking about her attempts weeks later was a good thing. She analysed what she would do in her ‘do-over’, how she should have handled the situation, and most importantly, how she would handle it better in the future.

Motivation theory also asserts that relatedness/fellowship between learners is important for ‘educational comfort’, for progress. For these participants, while fellowship was not unappreciated, its importance was acknowledged by how it directly provided help with solving the puzzles, rather than it being a cathartic sharing of the experience. While

participants appreciated the emotional support, this support was always a distant second to getting help to solve the puzzles. In this exploration at least, 'emotional relatedness' had an inverse relationship to 'cognitive engagement'.

However, the majority motivating reason for volunteering for this exploration was because of their personal relationship of sorts with the researcher, developed because of direct teaching contact with every participant (except for the 3 Industrial Design students). Even then, the 3 Industrial Design students' main reason for volunteering was because of their close personal relationship with one of the researcher's students who had asked them to volunteer. Without these relationships, there may have been few/no volunteers.

It is true that the relationship between this researcher (as module tutor) and the participants may have influenced the generation of data and subsequent analysis. The levels of enthusiasm displayed by individual participants would have been different with a different researcher. There was a pre-existing level of trust between the researcher and participants, and so there was a uniform expectation that this activity would be a worthwhile use of their time. The atmosphere in the pedagogic space was friendly and relaxed as this was a consequence-free environment regarding grades, but also because many of the participants had been in that office space before, for positive reasons such receiving extra instruction or guidance from the researcher. The literature supports the position that 'relatedness has a strong positive influence on motivation, and that external rewards reduce enthusiasm and engagement, that deadlines or punishments and any other similar pressures can undermine Intrinsic Motivation (Deci *et al.* 1999). While these types of relationships undoubtedly make any educational processes more pleasant for everyone involved, for research purposes it adds variable elements and raises questions.

The participants were encouraged to be brutally honest and were told that if they felt that this exploration was a terrible experience, they must declare this. It is the opinion of this researcher that they all accepted this fully, knowing that the objective of the research was a sincere effort to understand the student experience. However, as they were being told that their opinion was important to the researcher, this flattery may have affected their attitude in a much different way than if this exercise was part of a module run by a relative stranger, where their performance was under critical scrutiny, and with the external pressure of grading. It is acknowledged that the researcher's relationship

with the cohort was leveraged to obtain their services as volunteers and that it also 'pre-enthused' them. But, while 'relatedness' may have put them in the room and pre-enthused them, once there, their opinions were thoughtful reflections about how they felt about the experience, with sincere statements made during interview that were both complimentary and critical, and so can be considered as informative.

According to SDL's 'relatedness' theory, these relationships between teacher and student will always be a contributory, even defining factor in student motivation. But research warns that with such positive relationships, students can accidentally become dependent on being spoon-fed and not develop the critical thinking abilities needed to solve problems by themselves (Raelin 2006). How such research might be accomplished in a less contaminated setting is discussed in the 'Future Research' chapter.

Another intent of the pedagogic space was to create an atmosphere of freedom, and to examine how it was relevant. Participants found having real choices had a relaxing effect. Regarding this freedom, some students commented that they would have liked more guidance, specifically to know the most efficient order to attempt the puzzles. Participants did not want to be told what order to do things, but they did want to know what the best order was. A level of freedom allowed them to solve things their own way, even though these ways were quite limited as there was a design brief to be satisfied for the puzzle to be judged as solved.

Collective participant strategies depended on two factors: their personal problem-solving style and their first impressions of the puzzles. Some participants were enthusiastic, flitting between puzzles, chatting, and making jokes, while others probed in silence, grimly serious as they pondered their next step. For an example of personal problem-solving style, P24 requested a pen and paper during puzzle solving. She made a few indecipherable sketches for a minute or so, a unique event during testing.

Her undergraduate degree was in Fine Art, and she explained in interview that she often does this to help her think, see Figure 85 below. But she immediately went back to interacting directly with the puzzle in the ‘usual way’.

Figure 85 P24 sketching an idea

For another example, P8’s Smuggling Scarecrow solution involved using an elastic band. He attached the barrel to the cart with the elastic band. He carefully placed it inside the cart, and it passed the initial test of all three barrels being visible inside the carriage from the Policeman’s perspective. In the development stage of this puzzle, steps were taken to prevent any ‘just hang the barrel out of the carriage’ type of solutions. By placing The Policemen and The Batman on the same side with the same vantage point, any such solution would result in single position for the barrel that would either not pass The Policemen’s test, or not pass The Batman’s test. The inspiration for this puzzle was the use of natural forces to affect change. Therefore, all solutions must involve a change of state during the carriage ride upwards.

The only possibility for the ‘hanging the barrel outside’ solution to work would be for the barrel to be placed inside the carriage, pass the first inspection, then for it to fall out in transit (always on the side closest to the Policeman/Batman due to a deliberate angle on the track), but to somehow then jump across the track by itself while in transit up the slope, so that when the carriage arrived at The Batman’s position, the barrel would now be obscured by the carriage.

Which is exactly what happened, see Figure 86 and Figure 87 below. P8 jokingly claimed it was deliberate, but either way it fulfilled the requirements.

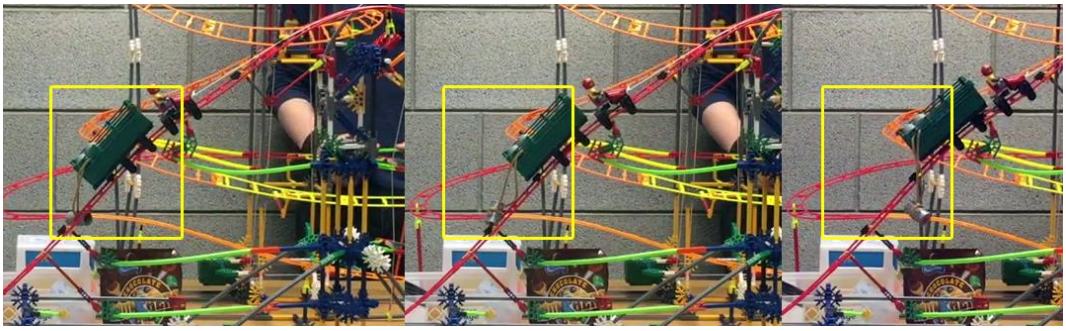


Figure 86 P8's Solution in Action

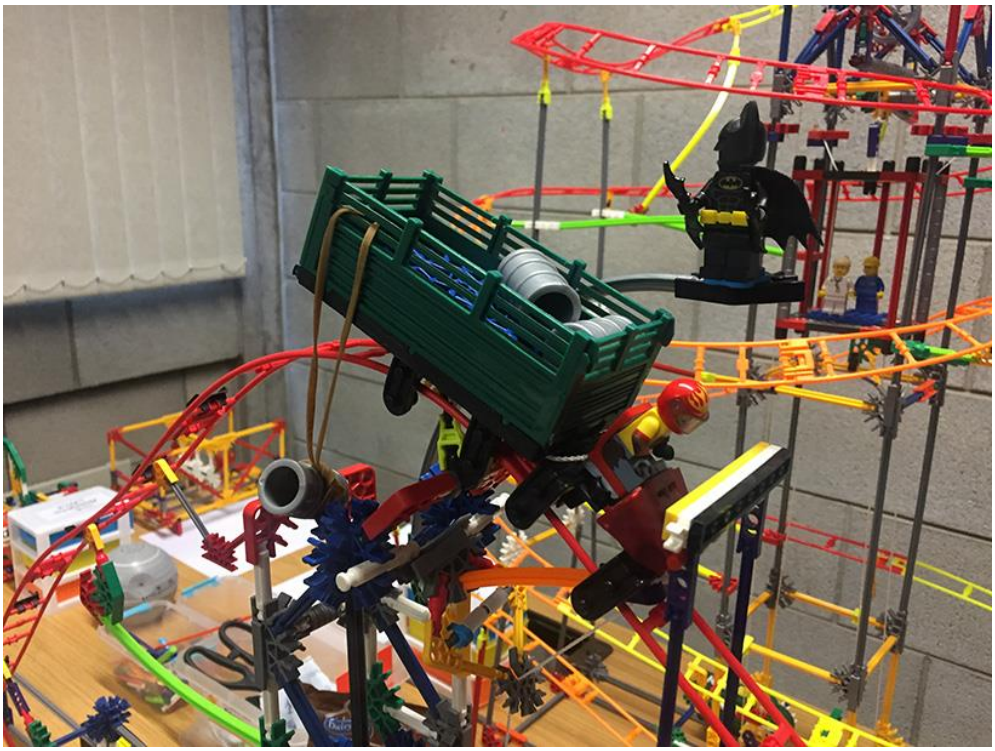


Figure 87 P8's Unique Solution

The freedom to attempt to reframe and solve as they saw fit, to quit at any time, where doing well or badly was of little consequence (externally at least) meant that this was a positive experience. Agentic Engagement was also manifested in participants' active weighing of the choices of how to work between puzzles, the order of which puzzle to try first, and whether to access clues or not. While some felt that if the clues were there then you should use them, the majority felt that it was giving in, even "cheating". This personalisation of the experience seemed to increase their investment in the whole

process. They knew that accessing of clues might reduce the learning aspect, but they cared much more about how accessing the clues hurt their pride, as they wanted to work it out on their own. They cared about their pride more than solving while engaged in the exploration, but afterwards they regretted that decision. This was always an emotional reaction, and never an intellectual one.

While individuals maintained their individual demeanours consistently, their physical behaviour changed when the physical puzzle changed. This is discussed in the next section (5.4).

5.4 Physical Interactions

There were 35 solves across all 3 puzzles, (see Table 62, below), during 75 opportunities for solving (3 x 25 pedagogic events).

	The Dalén Lamp	The Slow Elevator	The Scarecrow
Solved?	9	14	12
Not solved, but at least reframed?	6	7	6
No progress?	8	1	7
Attempts?	23/25	22/25	25/25

Table 62 Puzzle Solves & Puzzle Reframes

This does not mean that participants were only learning for less than half of the time (35 solves/75 attempts = 46.67%). Only five participants failed to solve at least one puzzle (P3, P4, P7, P13, P22), and all those participants successfully articulated a coherent reframing of at least one of the problem statements (P3 successfully reframed all three puzzles!). P4 ruminated that he "learned quite a bit about myself, actually. About myself, it was interesting to see, looking back, how I handled myself…being beaten by pieces of plastic...I was very interested how I enjoyed it", while P3 stated that she felt that she "learned a bit more about design in that 45 minutes than I probably have done in most of my design modules".

As there were 25 events (19 individuals & 6 pairs), there were 75 opportunities for puzzle solves (25*3 puzzles) by 31 participants. There were 35 solves, with 9 participants (5 individuals and 2 pairs) solving 1 puzzle, 15 participants (7 individuals and 4 pairs) solving 2 puzzles, and 2 participants (2 individuals) solving 3 puzzles. In addition, there were many 'almost-solves' with participants very close to solving, usually just running out of time. These examples of 'design thinking', when given in

lectures, are inspirational and aspirational. But it is always a passive experience, students being given the problem, then the context and thinking of the designer, and then the final solution, all in the space of a few minutes. Here, they were constructing their own knowledge by testing their own individual ideas, applying these to a new situation, and integrating the new knowledge gained with pre-existing intellectual constructs, for a deeper, personalised understanding.

Figure 88, see below, is a representative selection of the participants' differing physical approaches between The Dalén Lamp and The Slow Elevator.

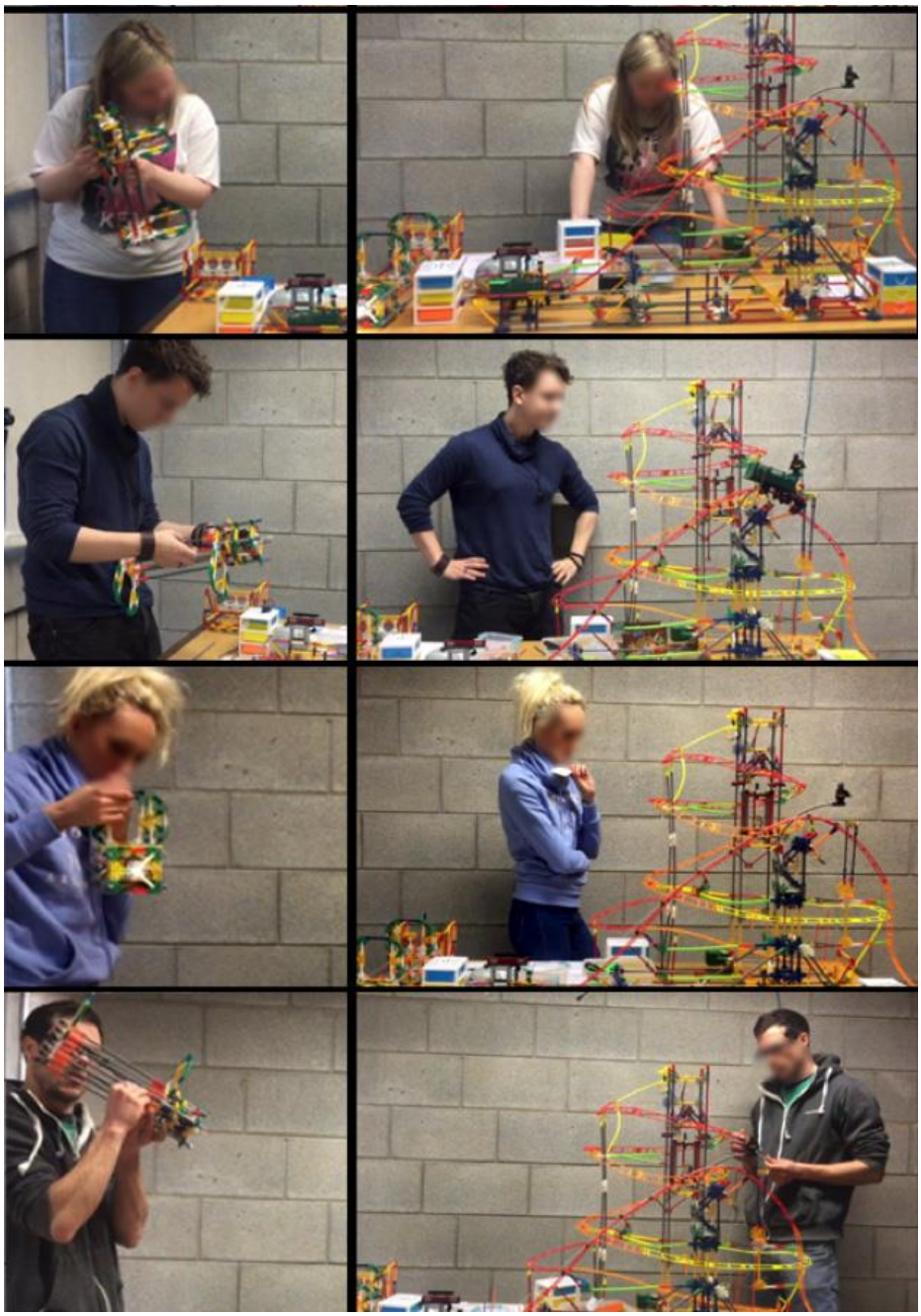


Figure 88 **Screen caps of participants' typical touching/not touching**

The analysis of all the participants' performances demonstrated that the physical nature of the puzzles affected their choices of puzzle order and their solving strategies. It also revealed that the participants interacted differently with each puzzle, with the physical structures of the puzzles dictating their solving strategies to an extent. They were particularly careful when manipulating The Slow Elevator for fear of breaking it, and they were restricted in their interactions with The Smuggling Scarecrow because any solution was focused on the contents of the stationary cargo-cart, so all their alterations were physically limited. But they felt free to do whatever they wanted to The Dalén Lamp. These changes in behaviour were because of the puzzles' physical nature, the freedom that the structure of each puzzle afforded the participants rather than the problem that the puzzle posed, (see Table 63 below), and is offered as explanation for why there was more variance in physical interactions with The Dalén Lamp than with either The Slow Elevator or The Smuggling Scarecrow.

Patterns in 'Not-Touching', 'Touching' and 'Building'	
Puzzle	**Statistical Summary**
The Dalén Lamp	($F(2,24) = 11.139$, $p = 0.00038$)
The Slow Elevator	($F(1,39) = 2.34$, $p = 0.1099$)
The Smuggling Scarecrow	($F(2,33) = 0.449$, $p = 0.642$)

Table 63 All Patterns in 'Not-Touching', 'Touching' and 'Building'

The structure of the puzzles, and the materials they were made from, affected the participants' strategies in several ways. The incremental nature of solving them was because of how K'Nex works, and how gravity would collapse the structures if due care were not taken. This encouraged an incremental, step-by-step approach. This proved to be a positive distraction from the little voice in their head that said, 'you won't understand'. The exposed nature of the puzzles' structures also had an effect, with participants capable of seeing how they could change things.

Regarding materials, the 9-dot K'Nex puzzle (in pre-testing) required winding a cord around the pegs, and seemed to be made more difficult by its physical form, whereas the 8-coin problem seemed to be made easier because of the physicality of the specific discs used, as they stacked in the hand quite naturally. The materials in this exploration also seemed to exert a constant influence.

However, their expressions of ‘relatedness’, their interactions with the Facilitator and/or their partner, were independent of the physical structure of the puzzle they were working on, see Table 64 below. It can be argued that the variances had more to do with their personality and its expression during an interesting activity.

Patterns in ‘Clarification’, ‘Encouragement’ and ‘Silence’	
Puzzle	**Statistical Summary**
The Dalén Lamp	($F(2,24) = 18.328$, $p = 1.47^{-5}$)
The Slow Elevator	($F(2,39) = 51.332$, $p = 1.19^{-11}$)
The Smuggling Scarecrow	($F(2,33) = 13.07$, $p = 6.59^{-5}$)

Table 64 All Patterns in ‘Clarification’, ‘Encouragement’ and ‘Silence’

The constants for social interaction across the different puzzles were the Facilitator and/or their partner. The physical structures of the puzzles were a separate issue, with the amount and type of human interactions being more related to the individuals’ general demeanour while concentrating on the puzzles. Some participants were exuberant and chatty, vocalising every inquiry and making continuous asides, while others were grimly serious and silent unless they really needed to know something, with other participants positioning themselves at various points across this spectrum.

While many of their eventual solutions were conceptually identical, the physical interactions and thinking patterns leading up to their solving of the problems were varied, individualistic in nature. The statistical results express the different physical approaches by participants between puzzles, something readily apparent by casually reviewing the video recordings. While the statisical expression of such differences is interesting, simply glancing at the charts is also informative regarding each individual’s activities, especially as it also provides direct, simultaneous comparison with their peers.

Figure 89, see below, is a compilation of the relevant information from all successful puzzle-solves. At a glance, it is clear there was more exploratory handling of The Dalén Lamp.

RED: Not-Touching; AMBER: Touching; GREEN: Building
BLUE: Clarification; Lt.GREEN: Encouragement; GREY: Silence

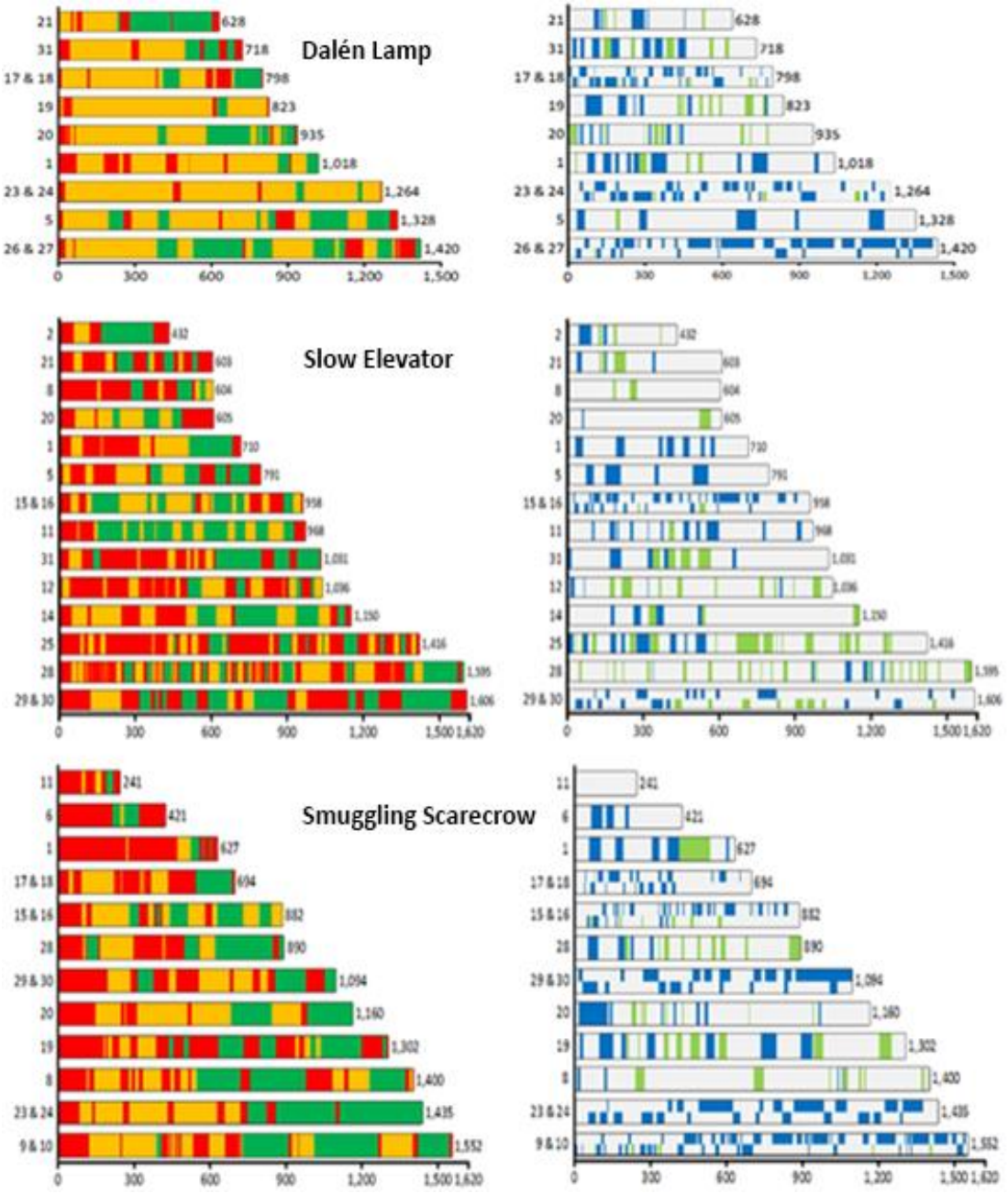


Figure 89 Compilation: All Puzzle Solves

Instead of watching those videos one at a time [32], (having to keep track of the types of the physical movements and usually simultaneously-occurring human interactions, and reasoning on their meaning), studying this chart can reveal information about their behaviours in relation to one another. But, to illustrate the difficulties of trying to represent the participants' activities with numbers alone, P8 & P21 serve as examples. These two participants solved The Slow Elevator in the same total amount of time (603/604 seconds), with similar totals for the categories of Not-Touching, Touching and Building, & for Clarification, Encouragement and Silence, see Figure 90, below.

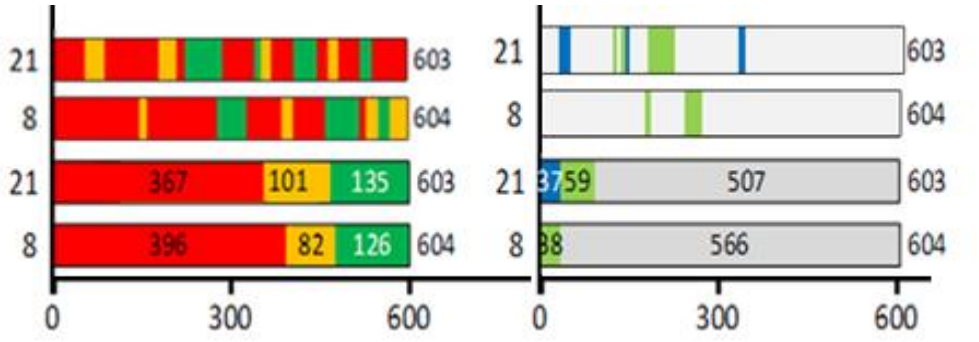


Figure 90 P8 & P21 Slow Elevator Comparison

P8 & P21's totals would indicate these performances for The Slow Elevator were very similar, but Figure 94's temporal breakdown of their activities showed that they varied considerably in their approaches, and reviewing the video recording (which is what this breakdown represents) reveals even more variance in their physical behaviour, something that numbers alone cannot capture. Figure 91, see below, presents the same two participants' activities across all puzzles.

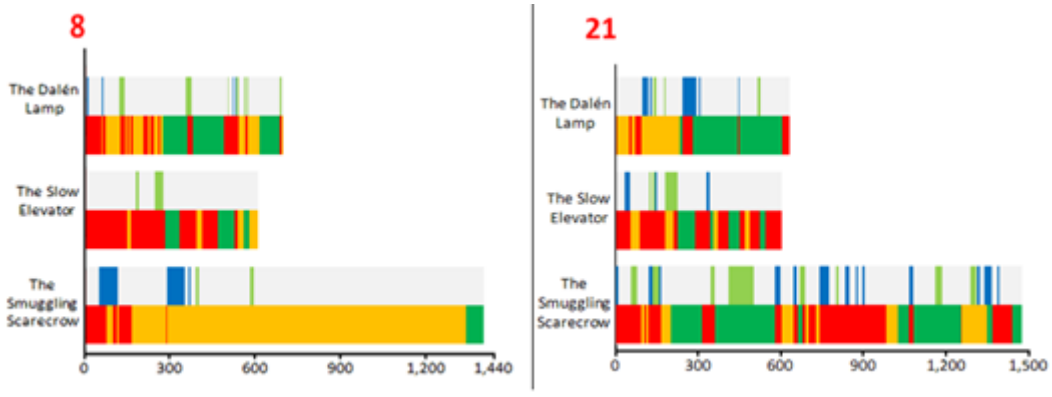


Figure 91 P8 & P21: All Activities

[32] Watching these selected videos alone, with no pausing or rewinding for analysis, takes over 19 hours.

P8, after a brief exchange of information with the Facilitator early on, remained silent while he constantly probed the mechanism, then built a solution rapidly when he was sure of what to do. P21 struggled with this puzzle, chatting constantly.

Studying that chart suggests that their performances with The Dalén Lamp were similar, but P8 didn't solve The Dalén Lamp, running out of time, while P21 solved it in the fastest time of all participants. Figure 92, see below, presents P21, 3 minutes and 50 seconds into his attempt; by then he had stripped The Dalén Lamp apart.

Figure 92 P21 stripping The Dalén Lamp

Figure 93, see below, presents P8 at 11 minutes into his attempt, seconds before his total time runs out. His general behaviour was more probing than P21's approach.

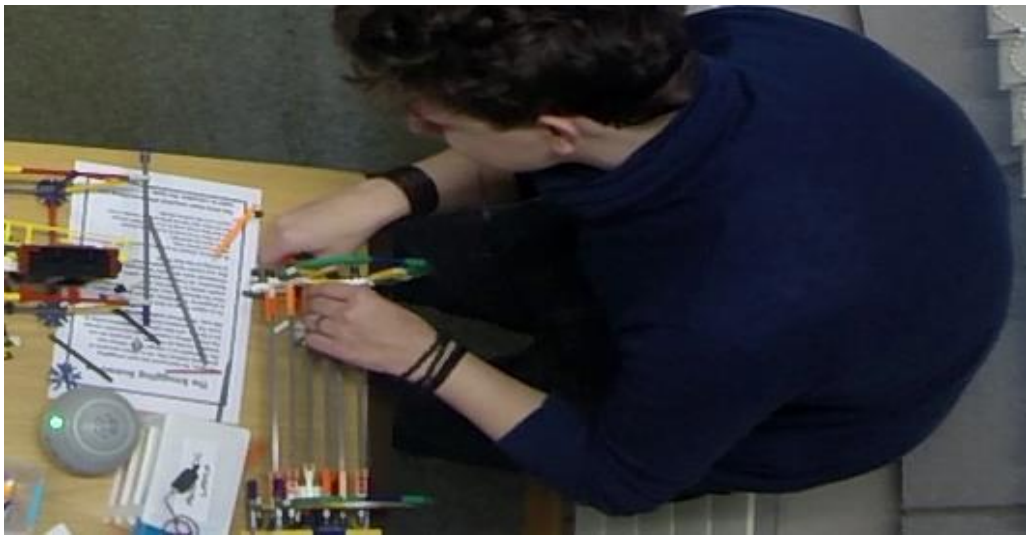


Figure 93 P8 not stripping The Dalén Lamp

The analysis of the participants' performances also demonstrated what they did with the freedom to move at will from puzzle-to-puzzle, to choose their own path, to access clues (or not). Clue access was their free choice. Regarding 'clue access', (in Figure 94, see below), the blue line relates to the single participants, and the yellow line relates to the paired participants. P1 was the best performing single participant and P17 & P18 were the best performing pairs. Every participant opened at least 1 clue, with only one participant opening all 9 clues. Regarding the differences in clue access between singles and paired participants, pairs were 1.5 times slower to access clues. One reason for this was that they always had to agree on actions, so moments of negotiation were required before they could access the clues as a pair.

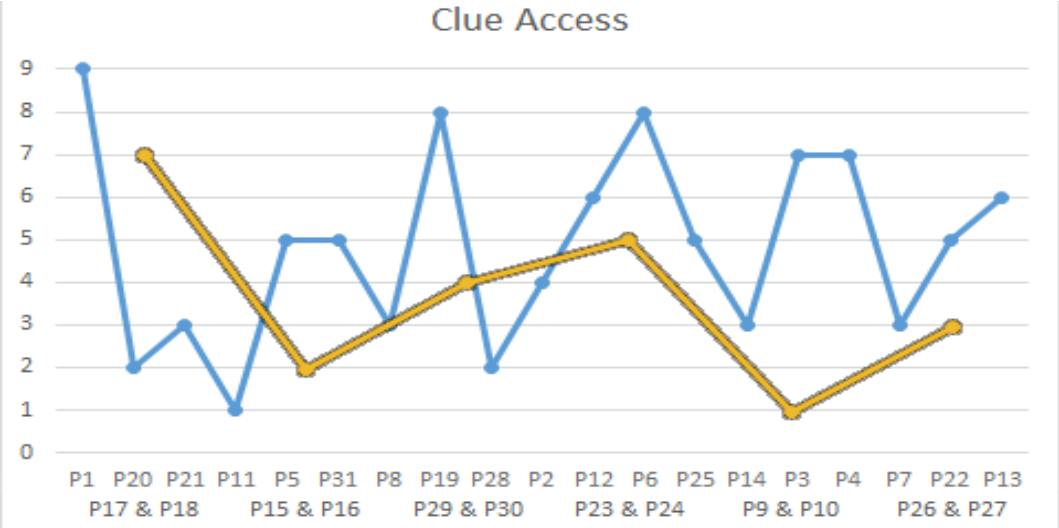


Figure 94 Clue Access

P1 & P20 solved all 3 puzzles, but P1 opened all 9 clues (the only participant to do so), and P20 only opened 2 clues for a single puzzle, when she was stuck and really felt that she had to. Every participant opened at least 1 clue.

P11 did not open any clues for the 2 puzzles he solved, only opening clues (1 of them) for the puzzle he struggled with. P21 did not open any clues for the 2 puzzles he solved, only opening clues (2 of them) for the puzzle he struggled with.

P19 & P28 (both Industrial Design 4th Years) solved 2 puzzles, but P19 happily opened 8 clues, and P28 resentfully opened only 2 clues, both for a single puzzle.

The purpose of this pedagogic intervention was always to provide an environment that engaged Interaction Design students with their design studies, creating an active

learning experience regarding problem reframing, instead of a passive one. Students are more likely to internalize and integrate a practice if they experience efficacy in engaging in it, have a connection with those who convey it, and choices with respect to it. Applying this Self-Determination theory in an educational context provided an environment that supported the development of the following (Silva *et al.* 2014):

1. Competence: This is the understanding of how to attain various external and internal outcomes and feeling effective in performing the requisite actions.
2. Relatedness: This involves developing secure and satisfying connections with others, feeling understood and cared for by others.
3. Autonomy: This refers to being self-initiating and self-regulating of one's own actions (self-determination), the feeling of being the originator of one's behaviours.

If distinct groups of patterns were uncovered, that would have been an interesting finding, regarding the validity of 'Learning Styles'. If Learning Styles is a valid pedagogical concept, then perhaps all 31 participant's results should have been split roughly into 4 or 5 distinctly related strategies, taking variances in these predicted numbers into consideration regarding the sample's population and size. Learning Styles makes a lot of intuitive sense. But no evidence-base has been developed to establish validation (Geake 2008; Riener & Willingham 2010). These results indicate that, when students were allowed to learn in their own way, they all chose different paths even though the experience was quite constrictive, with the puzzles and setting being the same for everyone.

In contrast, the strictest application of Constructivism would predict that, as all learners learn differently, then an externalisation of their cognitive processes should demonstrate exactly that, with all learners being distinctly different from one another. The results from this exploration certainly favour the strict Constructivist position and stand in opposition to Learner Styles. Reducing participant activities to numerical expressions was eventually informative, and the resulting charts (Figure 89, p.177) are a summary of hours of recordings, providing a tentative basis for claiming that while these 31 learners were always conscious of their individuality, they also all learned in individual ways, if their observable activities were indeed representative of the internal learning process.

5.5 The Usefulness of the Academic Motivation Scale

The Academic Motivation Scale is an evidence-based, reliable system of assessing individual motivational levels, as there are thousands of academic citations, uniformly commendatory in nature (Fairchild *et al.* 2005). Obviously with n=31, no definitive statement that either contradicts or reinforces the AMS' robustness can be made. But what is now presented is a comparative analysis of 6 pairs of individual participants (sections 5:4:1–5.4:6). Their performances, their timelines and their AMS scores are examined and compared. These results, presented in this manner, stress the individual differences displayed by the participants. This revisits the previous argument that a core element of Constructivism is that every individual's learning process is unique, while Learning Styles is a system of grouping similar types of leaners together (Eftekhar and Strong 1998). While there did not appear to be any substantive patterns between them when every participant was compared against each other, directly comparing their activities through the lens of their individual AMS scores provides some insights. Both Interaction Design and Industrial Design students are compared. While building models by hand is fundamental to Industrial Design studies and professional practice (Backett 2011) and this pedagogic environment would therefore seem to provide a natural advantage to Industrial Designers, it is again argued that the puzzles required the type of design thinking that is a core element of both cohorts' training.

5.5.1 P3 & P28

P3 & P28 were 4th Year Design students at the time of testing; P3 was Interaction Design, and P28 was Industrial Design. Both produced excellent FYP projects. P3 did not solve any puzzles; P28 solved 2 puzzles. P3 was able to articulate fine ideas for solutions for all 3 puzzles but struggled with even the first steps of creating any solutions, not knowing what to do with the information. P28 solved both The Slow Elevator and The Smuggling Scarecrow, solving The Scarecrow in the 4th fastest time. Figures 95-97 compare their individual performances, focussing on the activities: **Not-Touching/Touching/Building; Clarification/Encouragement/Silence.**

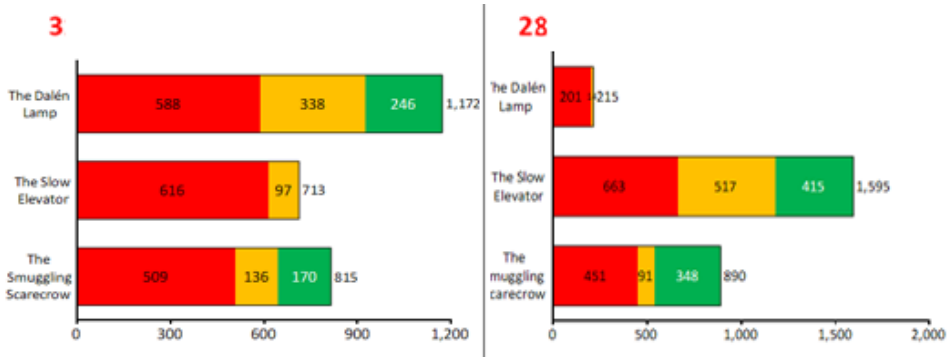


Figure 95 P21 & P31 NtTB

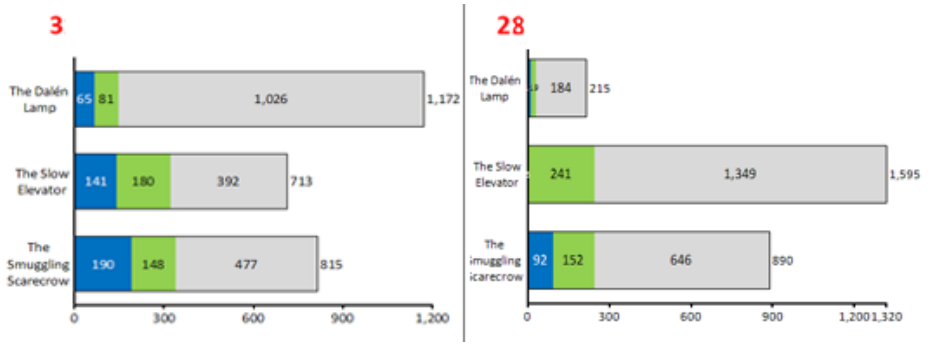


Figure 96 P21 & P31 CES

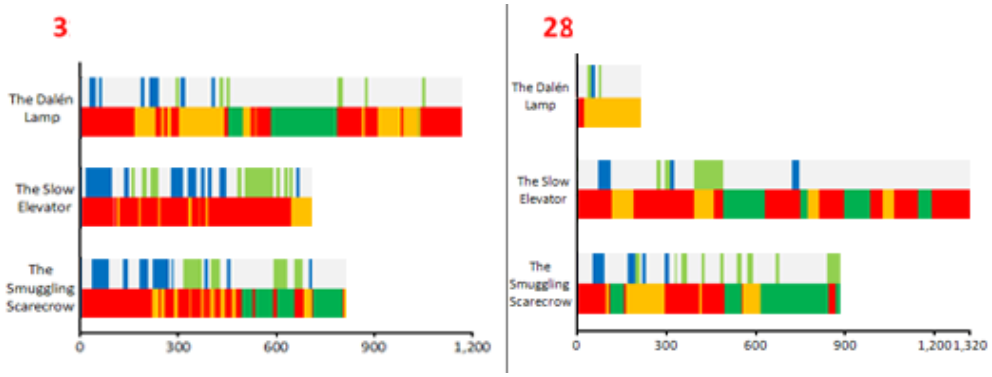


Figure 97 P21 & P31 Timelines

They had similar levels of academic training but performed very differently in the testing environment. Their scores for the AMS were also very different.

P3 scored the lowest for Intrinsic Motivation and very low for Extrinsic Motivation. P28 scored averagely for Intrinsic Motivation and for Extrinsic Motivation. Oddly, P3 scored 0% for Amotivation (as did 58% of the participants), while P28 scored 4.2%.

ID	Intrinsic	Placing	Extrinsic	Placing	Amotivation	Placing
P3	8.3%	31st	59.7%	25th	0%	31st
P28	72.2%	8th	79.2%	11th	4.2%	12th

Table 65 AMS for P21 & P31

These AMS scores (Table 65 above & Figure 98 below) indicate they were differently motivated, both in amount and type, a distinction seen as highly relevant in the motivation literature (Deci *et al.* 1991). They did perform differently. If the AMS is a predictor of engagement and/or ability, their performances were in line with the AMS results. P3's AMS scores were the 'worst' of all participants. Her interview revealed an individual questioning the validity of her training and her entire degree course. P28's interview conveyed the impression of a confident, disciplined individual.

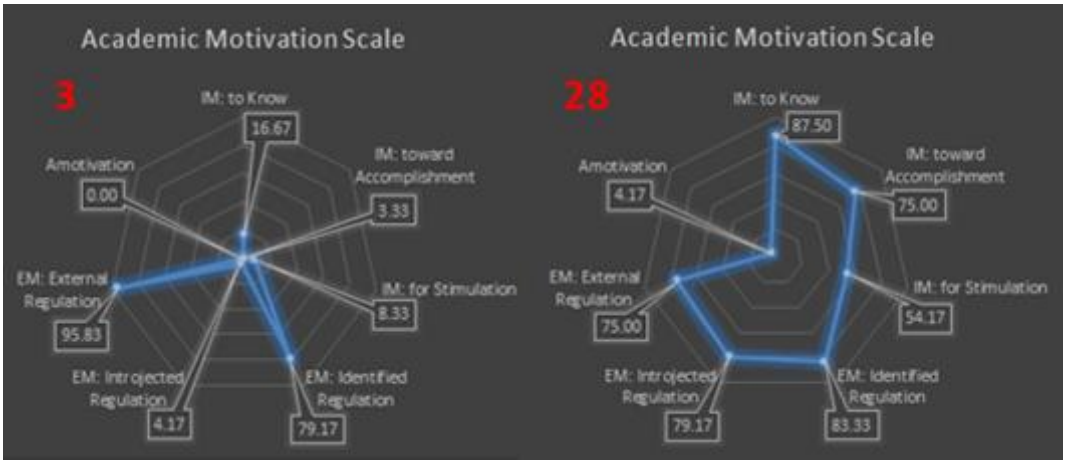


Figure 98 AMS for P21 & P31

However, this was the only comparison of this type that was possible to make: a comparative example of how AMS results can predict performance. 5 pairs of individual participants will now be presented, to see how their AMS scores and puzzle-solving activities related to one another. Or, more to the point, how they did not.

5.5.2 P21 & P31

P21 & P31 were both 3rd Year Interaction Design students at the time of testing; both excellent academics, and both produced excellent FYP projects. They both solved the same 2 puzzles. They had the 2 fastest solve times for The Dalén Lamp. Neither made any progress with The Smuggling Scarecrow, both struggling to grasp it at a conceptual level in much the same way.

Figures 99-101 compare their individual performances, focussing on the activities: **Not-Touching/Touching/Building; Clarification/Encouragement/Silence.**

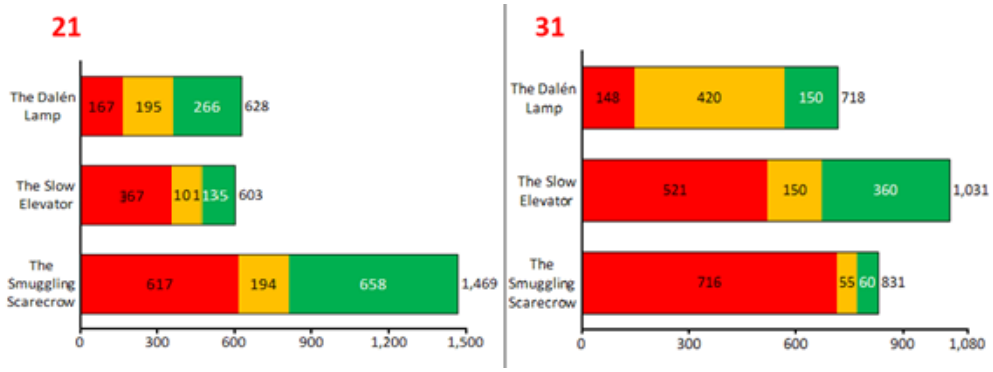


Figure 99 P21 & P31 NtTB

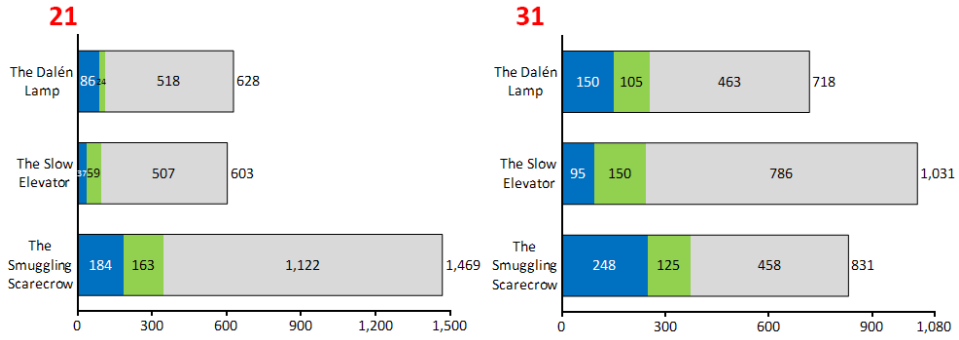


Figure 100 P21 & P31 CES

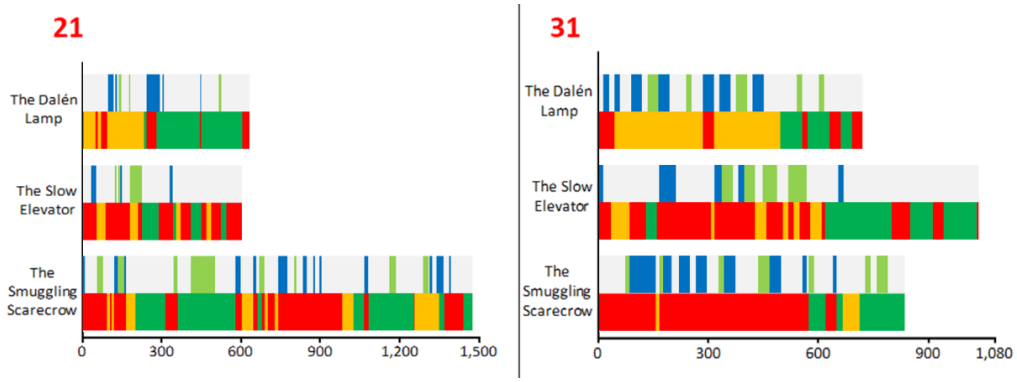


Figure 101 P21 & P31 Timelines

They had similar levels of training, experience and general academic performance, and a very similar performance in my testing environment. But their scores for the AMS are very different. Yes, they both scored 0% for Amotivation, but again, so did 58% of the participants.

P21 scored averagely for Intrinsic Motivation and very low for Extrinsic Motivation. P31 scored lower for Intrinsic Motivation and very high for Extrinsic Motivation.

ID	Intrinsic	Placing	Extrinsic	Placing	Amotivation	Placing
P21	70.8%	11th	56.9%	28th	0%	31st
P31	61.1%	16th	87.5%	5th	0%	31st

Table 66 AMS for P21 & P31

These AMS scores (Table 66 above & Figure 102 below) suggest they were differently motivated, both in amount and type. But they did not perform any differently.

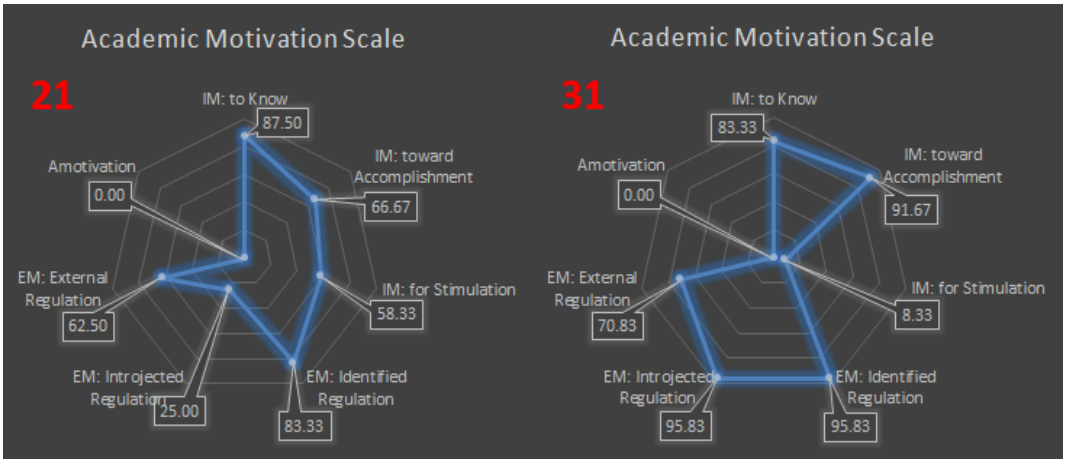


Figure 102 AMS for P21 & P31

P21's exceptional performances led to an overall ranking of 3rd.

P31's exceptional performances led to an overall ranking of 5th (tie).

5.5.3 P5 & P11

P5 & P11 were both 4th Year Interaction Design students at the time of testing. They both produced excellent FYP projects. They both solved 2 puzzles. Both solved The Slow Elevator. P5 solved The Dalén Lamp, but narrowly ran out of time with The Smuggling Scarecrow. P11 solved The Smuggling Scarecrow, but narrowly ran out of time with The Dalén Lamp. Figures 103-105 compare their performances regarding **Not-Touching**/**Touching**/**Building**; **Clarification**/**Encouragement**/**Silence**.

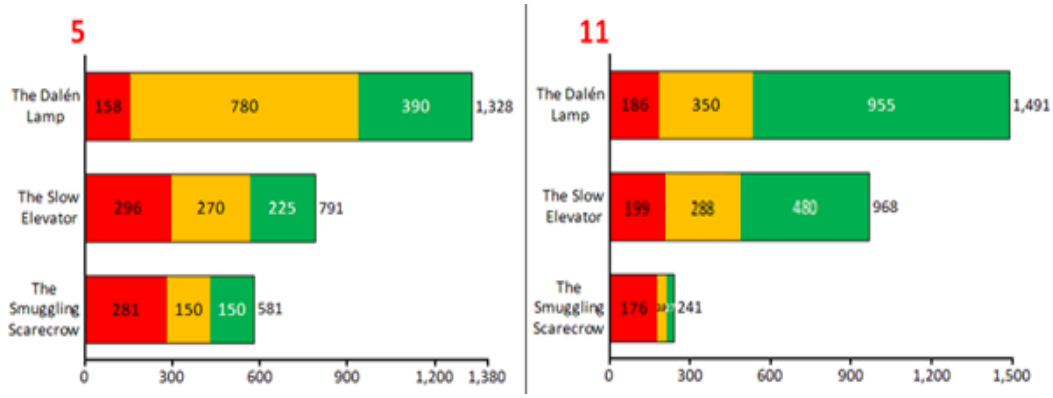


Figure 103 P5 & P11 NtTB

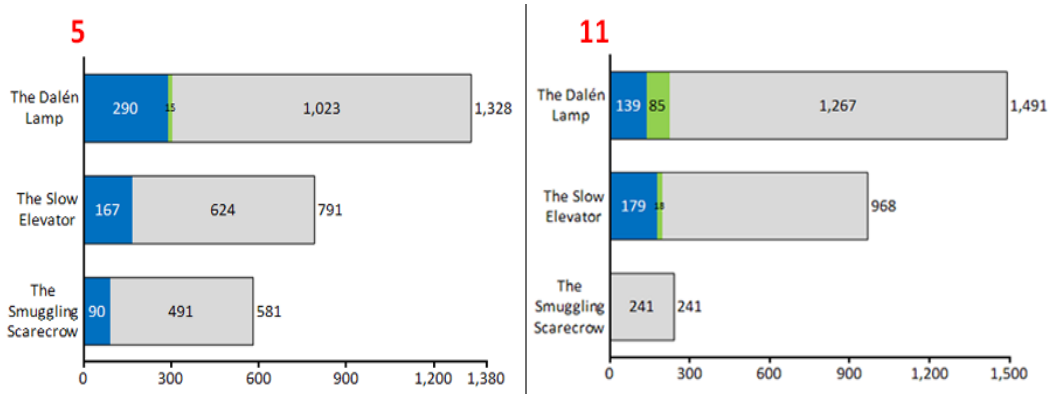


Figure 104 P51 & P11 CES

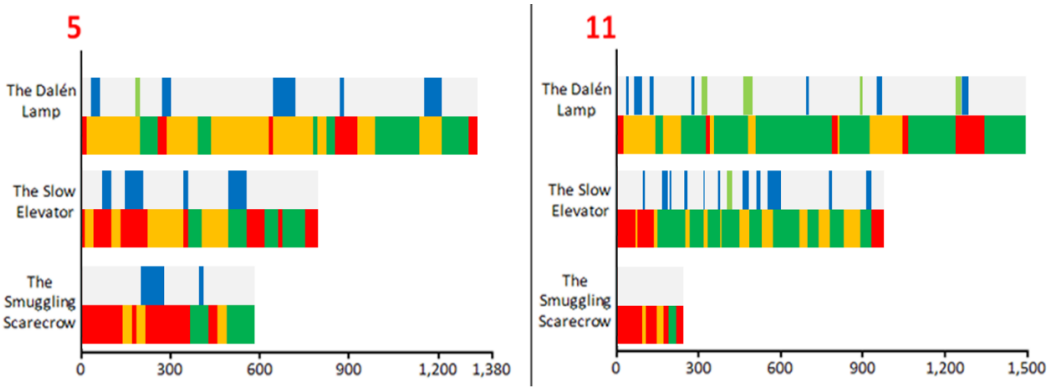


Figure 105 P5 & P11 Timelines

Both performed well, (and very similarly), in this exploration. But they are very different as students, with P5 finding academic work quite easy and P11, self-admittedly, much less so.

P5 scored very high for both Intrinsic Motivation and for Extrinsic Motivation.

P11 scored very low for both Intrinsic Motivation and for Extrinsic Motivation.

ID	Intrinsic	Placing	Extrinsic	Placing	Amotivation	Placing
P5	76.4%	4th	88.9%	3rd	0%	31st
P11	34.7%	29th	58.3%	27th	0.0%	31st

Table 67 AMS for P5 & P11

If the AMS is a valid predictor of motivation, and this translates into a predictor of engagement and/or performance, Table 67 above & Figure 106 below suggest that P5 would perform much better than P11.

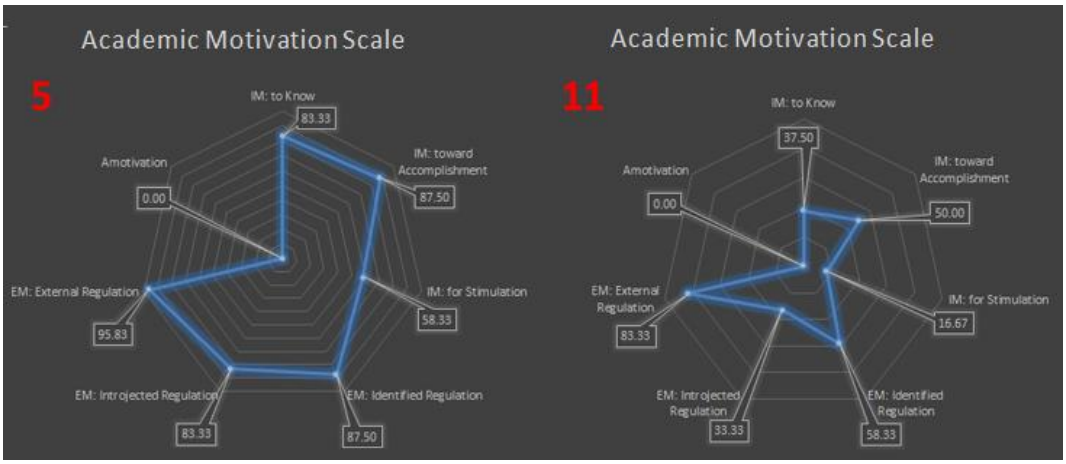


Figure 106 AMS for P5 & P11

However, while P5 'outguns' P11 in every aspect of academic study, (and got a much 'better' score in the AMS), when they were thinking with their hands, their exceptional performances were equivalents.

P5's exceptional performances led to an overall ranking of 5th (tie).

P11's exceptional performances led to an overall ranking of 4th.

5.5.4 P8 & P14

P8 was a 1st Year and P14 was a 3rd Year at the time of testing, and both were Interaction Design students. P8 solved 2 puzzles and P14 solved 1 puzzle. Both solved The Slow Elevator. P8 solved The Slow Elevator in the 3rd fastest time, and P14 solved it in the 11th fastest time (out of 14 solves). P8 also solved The Smuggling Scarecrow and did well with The Dalén Lamp, almost solving all 3 puzzles. P14 struggled to get anywhere at all with either of the other 2 puzzles. Figures 107-109 compare their performances in:

Not-Touching/Touching/Building; Clarification/Encouragement/Silence.

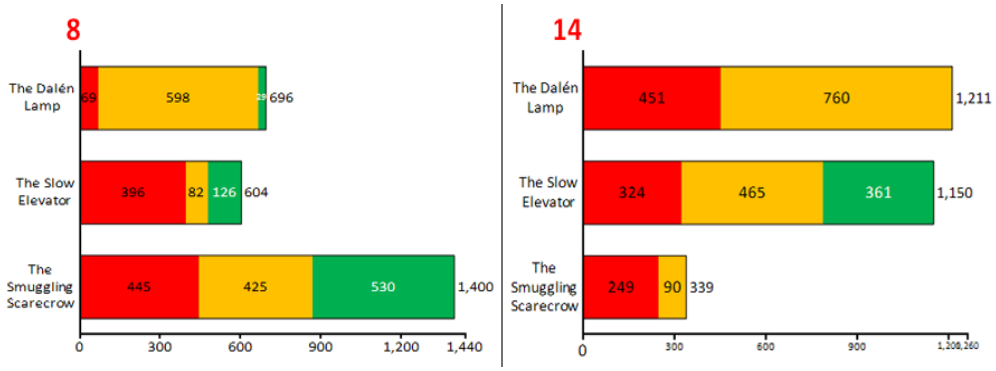


Figure 107 P8 & P14 NtTB

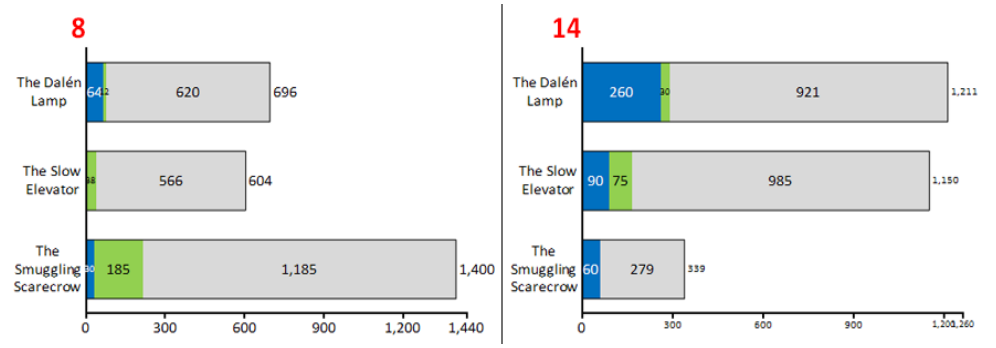


Figure 108 P8 & P14 CES

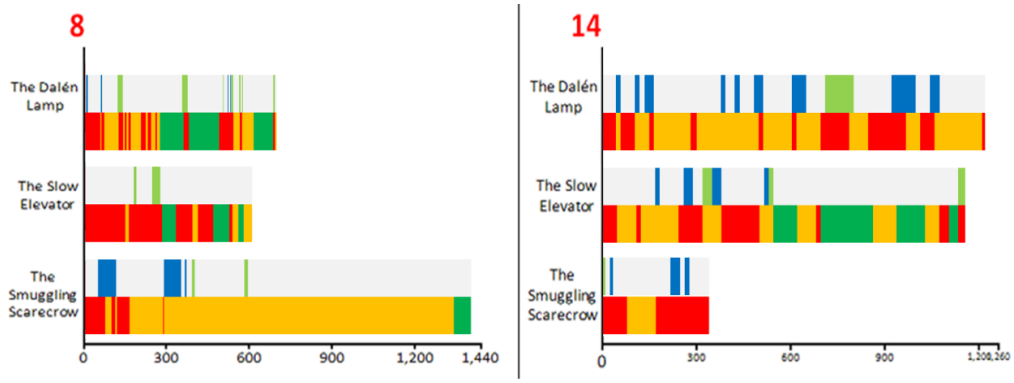


Figure 109 P8 & P14 Timelines

Both were at different stages of study and life experience. P8 was a traditional student (from Leaving Cert. straight to university), while P14 was a mature student.

P8 scored very low for Intrinsic Motivation and even lower for Extrinsic Motivation. P14 scored very high for both Intrinsic & Extrinsic Motivation.

ID	Intrinsic	Placing	Extrinsic	Placing	Amotivation	Placing
P8	43.1%	26th	54.2%	30th	8.3%	8th
P14	80.6%	3rd	83.3%	6th	0.0%	31st

Table 68 AMS for P8 & P14

These AMS scores (Table 68 above & Figure 110 below) suggest they were differently motivated, both in amount and type. P8 had a much lower score in both classifications of Motivation and less experience and training than P14. But their performances were radically different, and perhaps the opposite of what was predicted by the AMS.

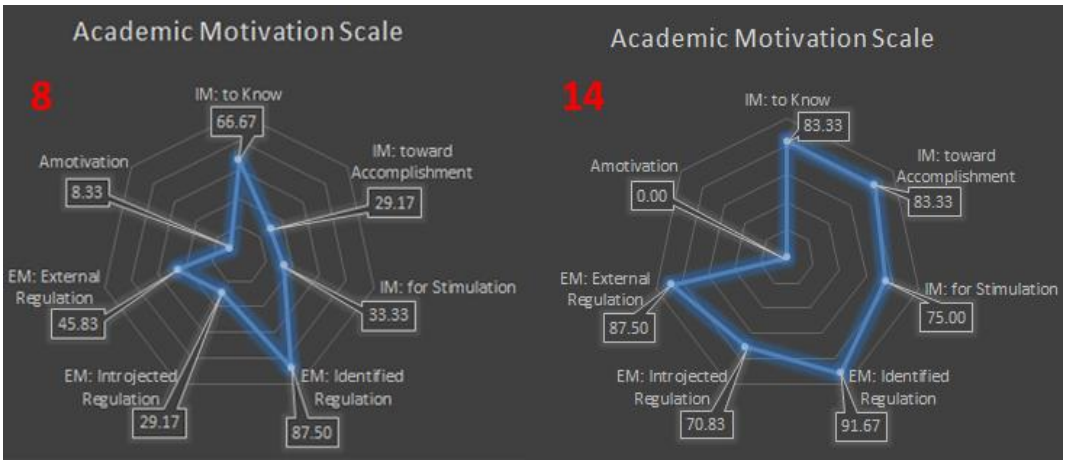


Figure 110 AMS for P8 & P14

P8's exceptional performances led to an overall ranking of 7th.

P14's overall ranking was 14th out of 19.

5.5.5 P19 & P22

P19 and P22 were both 4th Year Industrial Design students at the time of testing. P19 solved 2 puzzles and P22 did not solve any. P19 solved both The Smuggling Scarecrow and The Dalén Lamp, one of only 3 single participants to do so[33]. P19 solved The Dalén Lamp in the 3rd fastest time, and The Smuggling Scarecrow in the 6th fastest time. P22 struggled to get anywhere with any of the puzzles. Figures 111-113 compare their performances regarding **Not-Touching**/**Touching**/**Building**; **Clarification**/**Encouragement**/**Silence**.

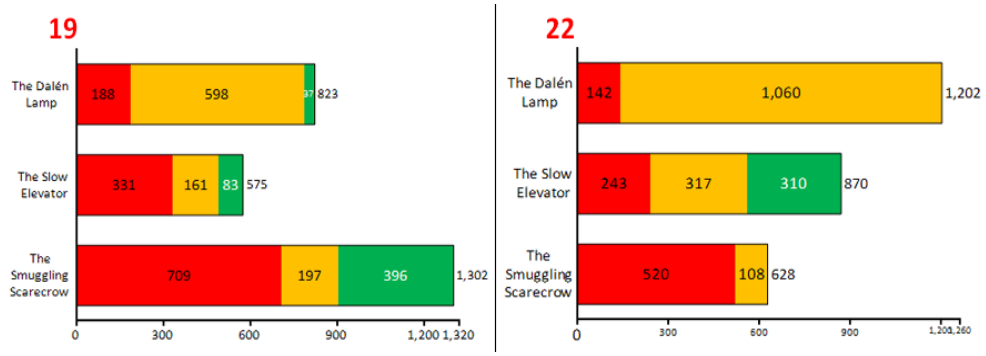


Figure 111 P19 & P22 NtTB

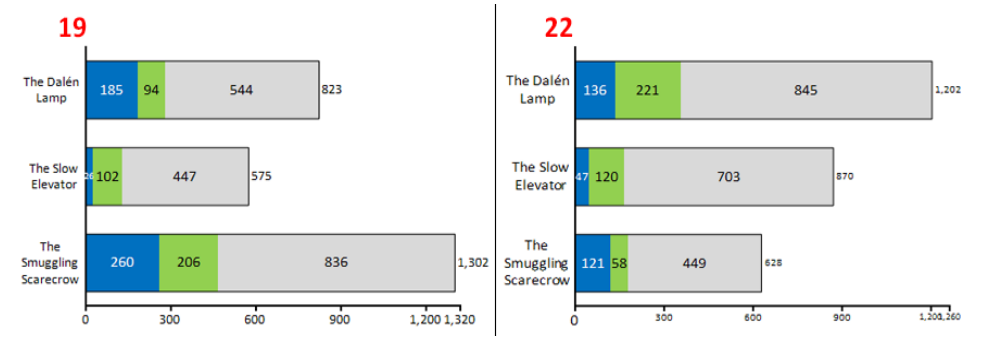


Figure 112 P19 & P22 CES

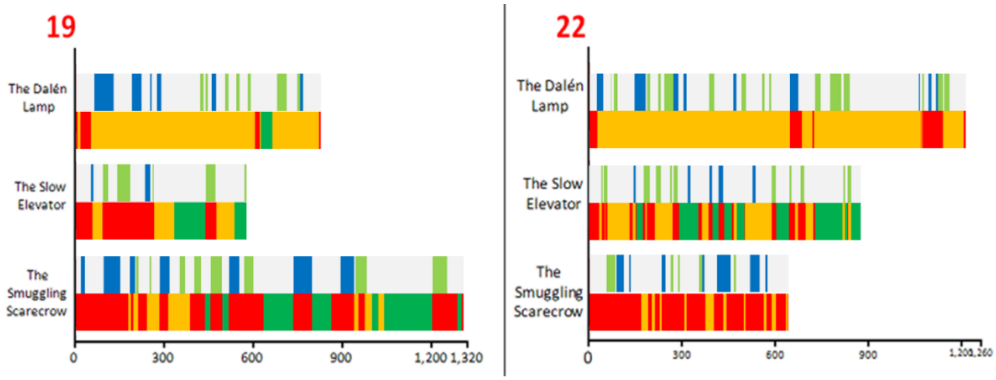


Figure 113 P19 & P22 Timelines

[33] The other 2 individuals were the students who solved all 3 puzzles. Also, 1 pairing (P17 & P18) did this.

P19 scored averagely for Intrinsic and Extrinsic Motivation and 0% for Amotivation. P22 scored a little lower in all three categories.

ID	Intrinsic	Placing	Extrinsic	Placing	Amotivation	Placing
P19	72.2%	8th	76.4%	14th	0%	31st
P22	65.3%	12th	72.2%	18th	8.3%	8th

Table 69 AMS for P8 & P14

In context, both participants scored almost the same in the AMS, the only real difference being P19's slightly higher score for 'the joy of learning'; see Table 69 above & Figure 114 below. Both were at the same stage of study and life experience, lived and socialised together but choose to participate separately. However, their performances were radically different.

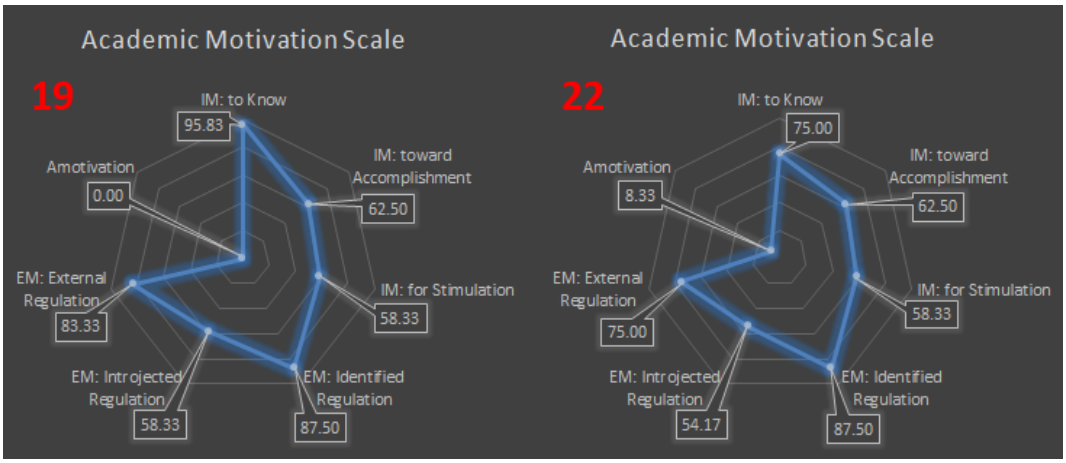


Figure 114 AMS for P19 & P22

P19's assured, exceptional performance led to an overall ranking of 8th.

P22's overall ranking was 18th out of 19.

5.5.6 P1 & P20

P1 was a 4th Year and P20 was a 2nd Year at the time of testing, and both were Interaction Design students. P1 & P20 both solved all 3 puzzles, the only participants to do so. Both performed at the same consistent level. With the Dalén Lamp, The Slow Elevator, and The Smuggling Scarecrow respectively; P1 placed 6th, 5th & 3rd; P20 placed 4th, 4th & 5th. Figures 115-117 compare their performances regarding

Not-Touching/Touching/Building; Clarification/Encouragement/Silence.

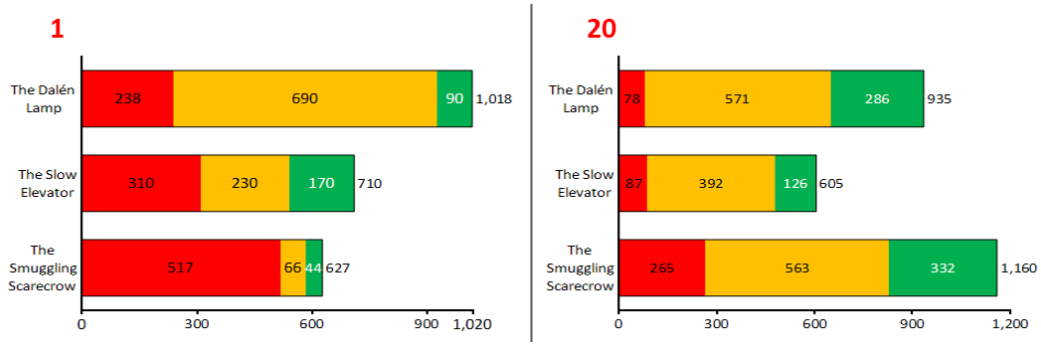


Figure 115 P1 & P20 NtTB

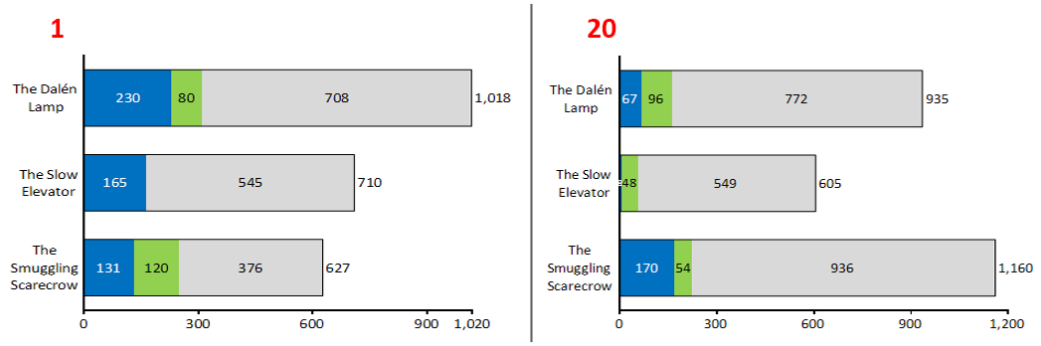


Figure 116 P1 & P20 CES

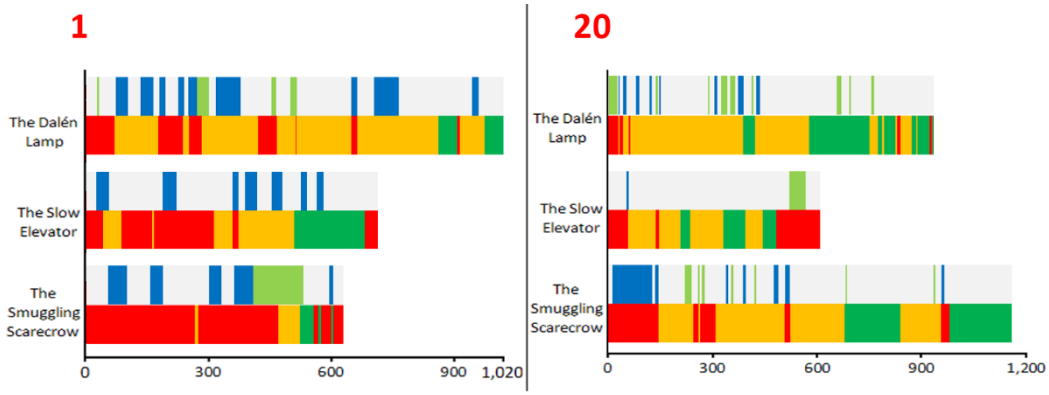


Figure 117 P1 & P20 Timelines

P1 scored low for Intrinsic Motivation and even lower for Extrinsic Motivation.

P20 scored very high for Intrinsic Motivation and low for Extrinsic Motivation.

ID	Intrinsic	Placing	Extrinsic	Placing	Amotivation	Placing
P1	52.8%	23rd	56.9%	28th	0%	31st
P20	83.3%	2nd	65.3%	22nd	4.2%	12th

Table 70 AMS for P1 & P20

Both participants scored differently in the AMS (see Table 70 above & Figure 118 below), especially regarding Intrinsic Motivation. Both were at different stages of study and life experience. P1 was a traditional student (from Leaving Cert. straight to university), while P20 was a mature student with professional model-making experience.

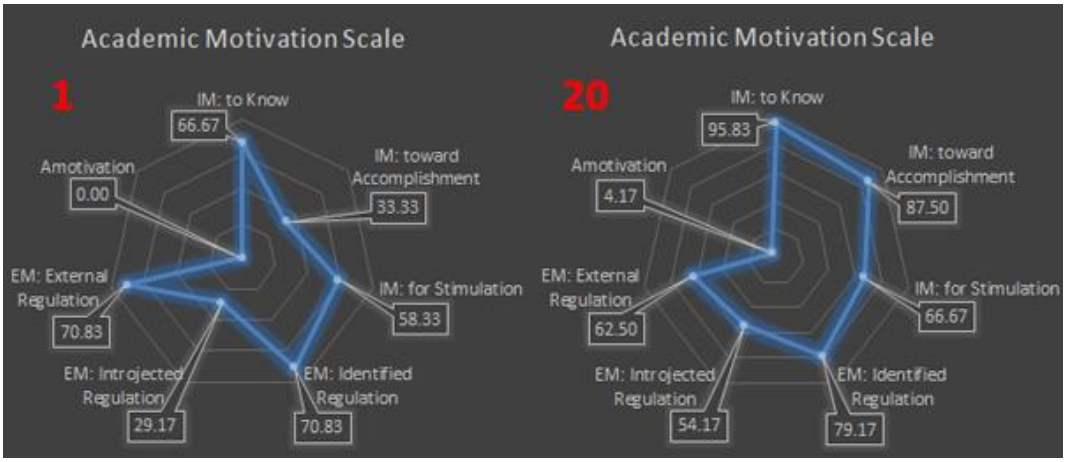


Figure 118 AMS for P1 & P20

Their performances were very different, with P1 exuberantly opening all 9 clues (the only participant to do so), despite not really struggling at any time. P20 was more thoughtful and probing, eventually only opening 2 clues (for the same puzzle) when she felt she needed to.

P1 finished all 3 puzzles within the time limit, and P20 finished just as the 45 minutes was up. P1 & P20's exceptional performances led to an overall ranking of 1st & 2nd place.

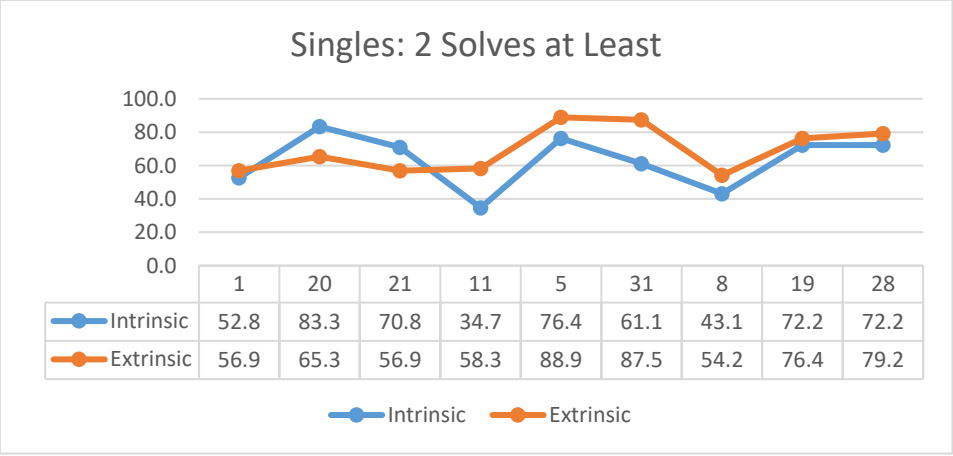
5.6 Intrinsic and Extrinsic Motivation

The term 'Motivation' is not subject-specific. It is 'Engagement' that is subject-specific. The level of an individual's motivation is hardly irrelevant and creating an educational environment that provides motivational support is inarguably good. But, while the Academic Motivation Scale is interesting, any findings from it are too general to be directly applicable to specific situations. Subject-specific engagement is a separate research area. All participants in this design research exploration were highly engaged (self-declared) with the process, either because of an interest in puzzles or an interest in assisting the researcher. But they varied wildly in their attitudes and opinions about their own course of study. Those with the same scores performed differently, participants with opposing scores performed similarly, etc. Most participants (84%) scored marginally higher for Extrinsic Motivation than Intrinsic Motivation. Only 5 participants produced a higher AMS score for Intrinsic Motivation (P7, P9, P10, P20 & P21), but as a grouping represent a spread across the performance range, see Table 71 below.

Participant ID =	**P7**	**P9**	**P10**	**P20**	**P21**
Puzzles Solved? (Average from 31 = 1.4)	**0**	**1**	**1**	**3**	**2**

Table 71 Intrinsically Motivated Participants

Table 72, see below, presents a snapshot of those single participants who solved at least 2 puzzles. The mean score for all participants for Intrinsic was 59.3%, and for Extrinsic was 72.7%.



	1	20	21	11	5	31	8	19	28
Intrinsic	52.8	83.3	70.8	34.7	76.4	61.1	43.1	72.2	72.2
Extrinsic	56.9	65.3	56.9	58.3	88.9	87.5	54.2	76.4	79.2

Table 72 Singles: 2 Solves at Least

Table 73, see below, presents the paired participants who solved at least 2 puzzles.

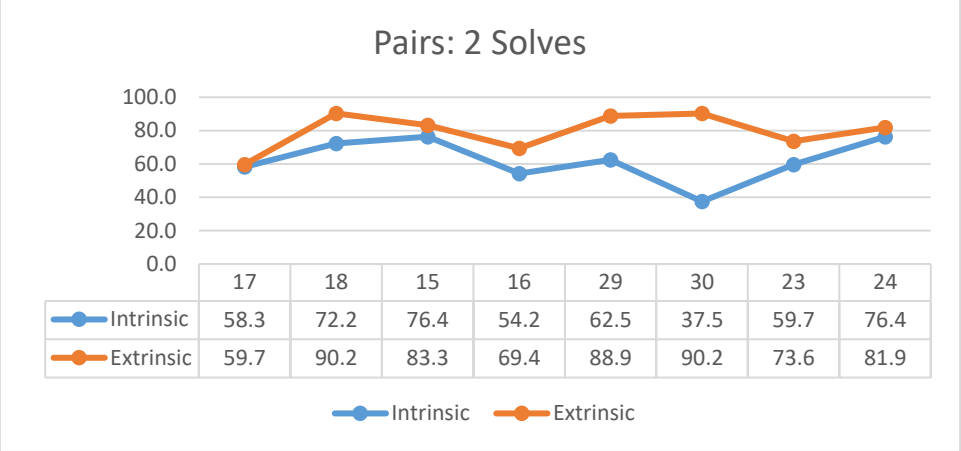


Table 73 Pairs: 2 Solves at Least

Based on observations of the strategies employed by the participants, an efficient way of solving these physical insight puzzles would have been a generic method of carefully absorbing the information at hand (including accessing the clues as early as possible), working out what were the variants and invariants, and then combining all of that as the foundation of the creative leap, of the 'reframing'. It is coherent on one level to state that the best strategy for solving was to access all the clues, and the best strategy for learning was to not access any clues. For example, it takes less than 4 ½ minutes to build all 3 puzzle solutions, if the solutions and how to realise them are already fully understood. For comparison, Figure 119, see below, is a compilation of each fastest individual performance from testing (P21, P2 & P11 respectively), for a total time of 21½ minutes.

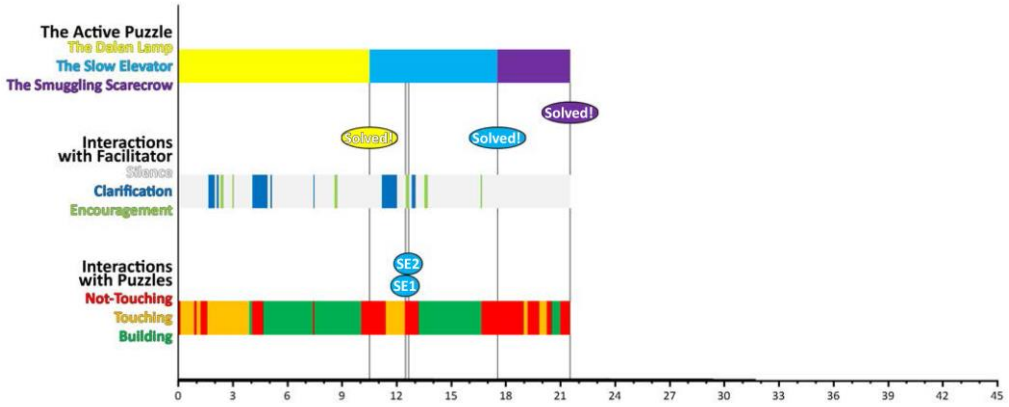


Figure 119 Compilation of Fastest Solves

However, the reality was far more complex than that. Almost all the participants felt that accessing clues was giving in, and they stubbornly refused this help until they felt they really needed to look at them. They all wanted to solve, to demonstrate competency to themselves. The clues presented a dilemma, between wanting to solve without any help, or giving in and accepting help. A stratagem of looking at the clues as soon it occurred, and not letting pride get in the way may have served them better.

In terms of engagement, the 'best way' of solving was for participants to use their autonomy as a way of claiming ownership over the entire process. Participants attempted to solve in their own way because they were allowed to do so. Some participants skipped back and forth between not-touching/touching/building with the puzzles, while others probed in a slow, deliberate fashion. They were all trying their best to solve, but in their own way.

Because of pride, they resisted the temptation of the clues, but realised afterward that the compromise of accessing them earlier would have been wiser. They knew it was a learning experience, designed to change their understanding of a concept, to change how they think. They thought long and hard about it afterwards. As only 2 participants solved all the puzzles, most 'post-mortems' of the event involved participants thinking about how they could, how they would do better next time.

The purpose of this exploration was to describe and understand rather than create and change, to contribute to an accumulated body of knowledge within the discipline of Interaction Design pedagogy. Part of that process was to provide a pedagogic environment that was engaging, where students would genuinely care about what they were learning. Here, students were constantly seeing the next 'event' as a way of continuing their success, or if having failed, to redeem themselves and improve on their performance. That is bordering on describing Intrinsic Motivation, a panacea for educational progress and development.

5.7 The Limitations of this Study

The study did have several limitations. For this research to be applicable to Interaction Design pedagogy, testing had to be with Interaction Design students, from all levels of experience, which was what happened. The pedagogical environment was based on a conceptual framework, with a theoretical framework applied to the design of the

exploration, and to the analysis of the resulting test data. Three Industrial Design students also participated (again, the argument is made for general applicability to Industrial Design students). All the participants wanted to volunteer. While this is normal for this level of research, it does mean that their level of enthusiasm may not have been representative of an entire cohort's level of enthusiasm. All of the volunteers participated for specific, positive reasons (an existing relationship with the researcher and/or liking puzzles), whereas an entire cohort of students, with a more varied mix of interests, motivation, and engagement levels, would have been a better sample.

This research is only directly applicable to Interaction Design students. This is appropriate because research into engagement can never be generalizable. If engagement is always subject specific, then a general theory of engagement is an oxymoron. While the lack of general applicability is a common criticism of educational research, any investigation into pedagogic engagement has to be subject-specific. In addition, the number of participants (n=31) was not large enough to state with any confidence that these were a replicable set of empirical findings. Both External Validity and Generalizability are also clearly undermined by researcher influence, bias, and n=31. The term 'Construct Validity' was discussed (Cook & Campbell 1979). In contrast to reliability, validity focuses on the relationships between indicators of theoretical concepts and theoretically relevant, external variables (Zeller & Carmines 1980).

So, instead of *reliability*, a better term for evaluating this study is *dependability*; not whether the results of one study would be the same as a second or third study, but whether the results of a study are consistent with the data collected (Merriam 1995). The non-generalizability of findings would be a fatal flaw if the goal were to design an evidence-based intervention to solve a specific problem. But, as the purpose of this research was to test explanatory theory, then Construct Validity is more relevant than other forms of external validity.

In addition, the researcher's active presence added variables, and without those variables the research findings would have been more robust. The presence and activities of the researcher were necessary to explore 'relatedness'. If a participant came alone, then the most direct way of exploring this topic was for the researcher to play a role of some description. If they came with a partner, then a similar role was fulfilled, but they were also free to interact with each other, another facet of 'relatedness'.

While it is true that a different researcher might produce different results, and draw different conclusions from those results, the literature maintains it is an important element to consider when analysing pedagogic motivation and must be understood more fully. So, a more appropriate framing of this argument is to replace ‘generalizability’ with ‘transferability’; where a study’s results can be transferred to situations with similar populations and characteristics (Lincoln & Guba 1986). As this study’s real-world scenario is a structured lesson as part of a formal design course, then the appropriate measure of rigour would be ‘ecological validity’; the exploration’s relevance to the real world (Brewer 2000).

Alan Peshkin cautioned that while this type of research is never objective in the traditional sense, research findings must always be verifiable. This is only possible if the reasoning behind an exploration’s design, the data collection methods used, and the analysis and subsequent interpretations are rigorous (1985). Any findings would not be objective per se, but verifiable because of the way the data was collected and analysed. Educational researchers treat all data as culturally saturated, reasoning that it cannot be divorced from its context (Mannix McNamara 2010). The blending of Education Research with established qualitative research methods has been described as a successful mixed marriage (Williamson *et al.* 2002).

There are, and always will be, profound difficulties in reaching an understanding of the complex relationship between the teacher and student, between the student and their peers, and especially the relationship between the student and their own mind. Researching education is about researching a complex series of relationships to produce actionable information. But, expecting to find one-to-one mappings to a reality that exists beyond the human mind is expecting to find a ‘Positivist Truth’, It is more appropriate to search for an ‘Interpretivist Truth’, where an interpretation conforms to the meaning given to it through the researcher's experience.

The possibility always existed that there were some alternative explanations for correlations that was never considered. As a result, this research is about accepting or rejecting these research hypotheses, but never proving them (Abowitz & Tootle 2010).

6 Conclusions

6.1 Introduction

The purpose of this research was to explore design pedagogy for Interaction Design students, to create a fresh perspective for the benefit of others. This research was a design study, with the aim to describe and understand rather than create and change, to contribute to a cumulative body of knowledge (Fallman 2008). Methods to help design students learn to think like designers already exist. This exploration could inform further research focussed on helping Interaction Design students develop their design thinking by engaging them physically, just as sketching does by helping the designer to create unintended consequences, what Donald Schön called a reflective conversation (1992).

By participating in this exploration, students enjoyed learning about reframing. But they also had their strengths and weaknesses exposed, on an individual basis. Some students were so quick to reframe correctly but struggled to realise their solution. Others were slow to reframe, but once they had, they found building a solution to be elementary. And they realised all of this about themselves in real-time. They left the pedagogic space knowing that they now had a concrete understanding of the abstract concepts of 'reframing an argument', and 'fixation'.

While on their journey to expertise, an individual's knowledge and experience can act as both an advantage and an impediment. Insight problems always present an impasse and require reframing, a new understanding that can come about suddenly. Insight in problem solving is also associated with the putting aside of information in memory, of dealing with the problem as if approaching it anew. This conflicts with the Constructivist concept of a 'schema'; where *all* thinking and understanding *must* be based on previous understanding and the subsequent assimilation of this new understanding into existing knowledge. In this exploration, the tension between one's knowledge of the world and overriding that knowledge to gain insight was manifested (Ohlsson 2011). Students' previous life experience and training, including their familiarity with the building materials themselves, at times helped them and at times were an impediment. Most participants were familiar with K'Nex, (having played with

it as children), and some of them attempted to build rather complex mechanisms when none were needed. The nature of The Scarecrow puzzle required an ‘outside-the-box’ type of reasoning. Launching into building a solution without any thoughtful consideration of the problem statement uniformly meant complete failure, and all such builds were abandoned in frustration. The more mechanical nature of The Dalén Lamp facilitated such immediacy, with some of the solvers creating rather complex trigger-type solutions with moving parts that worked as a valid solution. It was an interesting display of how their prior knowledge and skills affected their creativity.

The quantitative results categorised participant behaviour. The video analysis categories of 'Not-Touching', 'Touching' and 'Building' indicated that participants’ relatedness behaviour with their partner and/or me was consistent between puzzles, but their physical interactions were different for each puzzle (Zhang and Norman 1994). In addition, results from the Academic Motivation Scale were poor predictors of individual participant engagement. As participants displayed strong individualistic traits in opposition to what is predicted by Learning Styles theory, then teaching each subject in the best way for the subject matter at hand remains the best way. This does not contradict Ken Robinson’s ‘teach people, not subjects’ mantra. When you teach well, you express ideas and concepts with clarity so that your students understand. Whether the delivery method is lectures, workshops, or PBL, instructors must always focus on how best to communicate what they need to communicate.

This exploration was inspired by the concepts that underpin PBL in Medical Training but exchanged PBL’s ‘deductive thinking to solve well-defined problems’ with ‘abductive thinking to solve ill-defined problems’. Presenting concepts through tangible puzzles will never replace lectures, etc., in design training. But this idea, when more fully developed, could contribute to Interaction Design pedagogy.

For example, Problem-based Learning in Medical Training provides:

1. Factual knowledge (anatomy, neurology, pharmacology, pathology, etc.).
2. *Training in how to apply this knowledge through a deductive reasoning process, by presenting groups with a well-defined medical puzzle, designed explicitly to ‘change their minds’.*
3. Training in how to treat diseases.
4. Clinical placements in hospitals.

Interaction Design Training provides:

1. Factual knowledge (design principles, hardware and software training, research skills, etc.).
2. ???
3. Training in how to create and present a solution to a design brief.
4. Work placements in industry.

When Interaction Design students create a solution to a design brief, the process teaches them how to apply what they have been learning, crucially involving elements of abductive reasoning. But, PBL has that extra step, when it literally changes medical students' minds. They learn to think differently, to become doctors. This research project's aim is to describe and understand, and suggests a contribution to Interaction Design pedagogy would be that existing Interaction Design training methodologies could be supplemented by providing a 'Step 2':

> *Training in how to apply this knowledge through an abductive reasoning process, by presenting groups with an ill-defined design puzzle, designed explicitly to 'change their minds'.*

They cared about their experience because it had become personalised. There was an emotional investment, not just because they were solving a physical puzzle, but also because they were testing their competence in an intellectually and emotionally supportive environment, and by doing things their own way. They manifested Agentic Engagement by contributing "into the flow of the instruction they receive" (Reeve and Tseng 2011, p.2).

Many admitted to a default position of doubting their own abilities. This was relieved by the tangibility and incremental nature of the puzzles, where they focussed on the next step only. This was a distraction from the voice in their head telling them that they will not understand. Whether they solved all three puzzles or failed to solve any, they tacitly learned about both the concepts and about themselves in a productive way and were given to ruminating over their performance for many weeks.

Tangible re-imaginings of historical design examples (normally given in lecture) were

used in this exploration so that the student's experience could be active instead of passive. They could play the role of designer, knowing that a solution was possible, but placed under an intense time-pressure. It is often only under pressure that our true understanding reveals itself. The intense pressure in this exploration was generated, not by the time limit, but by each participant's determination to solve every tangible puzzle.

Tangibility affects our relationships with everything. Touching a loved one, touching a beautiful musical instrument, a beloved pet, these are all common, positive, sensual experiences. For this research, touching was an extension of the conscious mind, a mechanism for reasoning. Instead of staring into space contemplating, this pedagogical exploration encouraged Interaction Design students to learn tacitly, to think by touching, to reason with the physical, to think with their hands.

7 Future Research

7.1 Introduction

The sample size of this study was reasonable considering the depth of analysis required. However, a long-term, cross-sectional study would be far more useful. It would be elementary to scale up this pedagogical exploration. The puzzles used in this exploration could be replicated and these explorations run at a class-size scale, a comfortable fit by design. A single-period lesson could easily accommodate an introductory commentary on, for example, 'problem reframing'. Then the full class, split into pairs or small groups, could attempt to solve copies of the Dalén Lamp puzzle for 15/20 minutes. Then, a regrouping to discuss what they learned from the experience. A double-period lesson could easily accommodate all three of these puzzles.

The approach described in this thesis could help Interaction Design students on the journey to expertise, to practice becoming design decision-makers while learning about abstract concepts and practicing practical skills during their training programs (Guersenzvaig 2015). According to Weisberg, intuition is an automatic process that is built on acquired knowledge structures, but operating (at least partially) without conscious awareness, whereas conscious analysis is based on matching the problem with information in memory and making decisions based on that match (2015). Intuition is not operating independently of that knowledge but is a decision-making process that rises to the forefront of the mind, seemingly without explicit reasoning (Nelissen 2013). This ability to suddenly jump forward from 'design reasoning' to 'design intuition' is demonstrated by experienced designers.

Creating a pedagogic experience where Interaction Design students are presented with a problem and they must create a solution that is by nature incremental could encourage them to fail better. If their sense of personal pride were similarly invoked, this could improve the teaching of design students to think in a designerly way (Cross 2006). Pre-testing (and the testing itself) revealed that the materials used in any insight puzzle exert an influence over the thought processes regarding reframing. The structure of the K'Nex materials in this exploration certainly constrained the participants into taking incremental steps both physically and mentally.

This fits into the larger pedagogic landscape by creating an environment that encourages them to allow themselves to be changed by their educational experience. This is always a difficult process. These issues are compounding by the context for this research: The Irish Educational system. Most Irish university students come directly from Second-Level schooling, which concludes with the Leaving Certificate examination. A major criticism, especially relevant to this thesis, is that it favours memory recall rather than anything else (Burns *et al.* 2018). This is clearly not a coherent strategy for preparing any student for a university course where they will be required to think critically. As design by its nature requires creativity, this system is especially damaging to prospective design students and presents many issues for university design instructors to deal with, especially students' general inability to think productively in an academic setting.

This research explored 'tacit knowledge'; knowledge difficult to transfer by words or writing and can only be acquired through practical experience in context (Reber 1989). Self-determined Learning differentiates motivation, with the type of motivation more important than the amount of motivation in predicting important outcomes. Autonomous motivation is increased when students are free to explore without external pressures. This type of motivation predicts persistence and effective performance, especially heuristic tasks that involve creativity (Amabile 1979; Sheldon 1995; Hennessey 2000).

An application of these findings would the development of educational experiences that would not be directly attached to grading, where design students could learn in a forgiving, supportive environment. The concept of 'fail better' is difficult to teach when the students cannot afford to fail.

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Appendix A

This appendix contains the raw data regarding the participants' puzzle-solving activities.

A1 Raw Data from Puzzle Solving Activities

All data is expressed in either seconds, or percentages.
Table 74, see below, presents the raw data from The Dalén Lamp attempts, regarding their 'Not-Touching', 'Touching' and 'Building' activities.

The Dalén Lamp							
Participant	**Not-Touching**	**%**	**Touching**	**%**	**Building**	**%**	**Total Time**
21	167	26.59	195	31.05	266	42.36	628
31	148	20.61	420	58.50	150	20.89	718
17&18	152	0.50	450	77.94	173	21.55	798
19	188	22.84	598	72.66	37	4.50	823
20	78	8.34	571	61.07	286	30.59	935
1	238	23.38	690	67.78	90	8.84	1018
23&24	49	3.88	1170	92.56	45	3.56	1264
5	158	11.90	780	58.73	390	29.37	1328
26&27	527	37.11	338	23.80	555	39.08	1420
Not Solved							
11	186	12.47	350	23.47	955	64.05	1491
15&16	120	13.95	489	56.86	251	29.19	860
2	377	25.17	726	48.46	395	26.37	1498
3	588	50.17	338	28.84	246	20.99	1172
12	548	55.92	277	28.27	155	15.82	980
25	220	39.29	340	60.71	0	0.00	560
6	185	30.83	400	66.67	15	2.50	600
8	69	9.91	598	85.92	29	4.17	696
22	142	11.81	1060	88.19	0	0.00	1202
14	451	37.24	760	62.76	0	0.00	1211
9&10	198	17.63	925	82.37	0	0.00	1123
4	609	90.63	63	9.38	0	0.00	672
28	201	93.49	14	6.51	0	0.00	215
7	180	23.08	600	76.92	0	0.00	780
29&30	Not Attempted						
13	Not Attempted						

Table 74 Raw Data from The Dalén Lamp: NtTB

Table 75, see below, presents the raw data from The Dalén Lamp attempts, regarding their ‘Clarification’, ‘Encouragement’ and ‘Silence’ activities.

The Dalén Lamp							
Participant	**Clarification**	**%**	**Encouragement**	**%**	**Silence**	**%**	**Total Time**
21	86	13.69	24	3.82	518	82.48	628
31	150	20.89	105	14.6	463	64.48	718
17&18	368	46.12	26	3.26	381	50.63	775
19	185	22.48	94	11.4	544	66.10	823
20	67	7.17	96	10.3	772	82.57	935
1	230	22.59	80	7.86	708	69.55	1018
23&24	630	49.84	15	1.19	619	48.97	1264
5	290	21.84	15	1.13	1023	77.03	1328
26&27	156	64.72	5	0.35	763	34.93	1420
Not Solved							
11	139	9.32	75	5.70	985	84.98	1491
15&16	103	45.00	337	0.58	870	54.42	860
2	183	12.22	241	10.9	1349	76.84	1498
3	65	5.55	0	6.91	1181	87.54	1172
12	57	5.82		10.6		83.57	980
25	30	5.36	64	14.8	835	79.82	560
6	240	40.00	120	7.50	703	52.50	600
8	64	9.20	155	1.72	1184	89.08	696
22	136	11.31	102	18.4	447	70.30	1202
14	260	21.47	180	2.48	392	76.05	1211
9&10	154	42.92	240	8.99	343	48.09	1123
4	59	8.78	240	9.67	944	81.55	672
28	12	5.58	0	8.84	9	85.58	215
7	106	13.59	192	24.6	482	61.79	780
29&30	Not Attempted						
13	Not Attempted						

Table 75 Raw Data from The Dalén Lamp: CES

Table 76, see below, presents the raw data from The Slow Elevator attempts, regarding their ‘Not-Touching’, ‘Touching’ and ‘Building’ activities.

The Slow Elevator							
Participant	**Not-Touching**	**%**	**Touching**	**%**	**Building**	**%**	**Total Time**
2	161	37.27	64	14.81	207	3.43	432
21	367	60.86	101	16.75	135	2.78	603
8	396	65.56	82	13.58	126	2.25	604
20	87	14.38	392	64.79	126	10.71	605
1	310	43.66	230	32.39	170	4.56	710
5	296	37.42	270	34.13	225	4.32	791
15&16	293	30.58	353	36.85	312	3.85	958
11	199	20.56	288	29.75	480	3.07	968
31	521	50.53	150	14.55	360	1.41	1031
12	503	48.55	398	38.42	135	3.71	1036
14	324	28.17	465	40.43	361	3.52	1150
25	896	63.28	298	21.05	222	1.49	1416
28	663	41.57	517	32.41	415	2.03	1595
29&30	671	41.78	245	15.26	690	0.95	1606
Not Solved							
17&18	132	10.93	775	64.16	301	5.31	1208
22	243	27.93	317	36.44	310	4.19	870
4	511	32.02	488	30.58	597	1.92	1596
19	331	57.57	161	28.00	83	4.87	575
3	616	86.40	97	13.60	0	1.91	713
13	485	69.29	215	30.71	0	4.39	700
6	686	44.00	873	56.00	0	3.59	1559
7	9	100.00	0	0.00	0	0.00	9
9 & 10	Not Attempted						
23 & 24	Not Attempted						
26 & 27	Not Attempted						

Table 76 Raw Data from The Slow Elevator: NtTB

Table 77, see below, presents the raw data from The Slow Elevator attempts, regarding their ‘Clarification’, ‘Encouragement’ and ‘Silence’ activities.

The Slow Elevator							
Participant	**Clarification**	**%**	**Encouragement**	**%**	**Silence**	**%**	**Total Time**
2	50	11.57	17	3.94	365	84.49	432
21	37	6.14	59	9.78	507	84.08	603
8	0	0.00	38	6.29	566	93.71	604
20	8	1.32	48	7.93	549	90.74	605
1	165	23.24	0	0.00	545	76.76	710
5	167	21.11	0	0.00	624	78.89	791
15&16	104	46.76	29	3.03	481	50.21	958
11	179	18.49	18	1.86	771	79.65	968
31	95	9.21	150	14.5	786	76.24	1031
12	35	3.38	132	12.7	869	83.88	1036
14	90	7.83	75	6.52	985	85.65	1150
25	209	14.76	337	23.8	870	61.44	1416
28	5	0.31	241	15.1	1349	84.58	1595
29&30	180	26.46	0	0.00	1181	73.54	1606
Not Solved							
17&18	60	25.58	64	5.30	835	69.12	1208
22	47	5.40	120	13.8	703	80.80	870
4	257	16.10	155	9.71	1184	74.19	1596
19	26	4.52	102	17.7	447	77.74	575
3	141	19.78	180	25.3	392	54.98	713
13	117	16.71	240	34.3	343	49.00	700
6	375	24.05	240	15.4	944	60.55	1559
7	0	0.00	0	0.00	9	100	9
9 & 10	Not Attempted						
23 & 24	Not Attempted						
26 & 27	Not Attempted						

Table 77 Raw Data from The Slow Elevator: CES

Table 78, see below, presents the raw data from The Smuggling Scarecrow attempts, regarding their 'Not-Touching', 'Touching' and 'Building' activities.

The Smuggling Scarecrow							
Participant	**Not-Touching**	**%**	**Touching**	**%**	**Building**	**%**	**Total Time**
11	176	73.03	38	15.77	27	11.20	241
6	331	78.62	15	3.56	75	17.81	421
1	517	82.46	66	10.53	44	7.02	627
17&18	456	65.71	98	14.12	140	20.17	694
15&16	416	47.17	198	22.45	268	30.39	882
28	451	50.67	91	10.22	348	39.10	890
29&30	194	17.73	675	61.70	225	20.57	1094
20	265	22.84	563	48.53	332	28.62	1160
19	709	54.45	197	15.13	396	30.41	1302
8	445	31.79	425	30.36	530	37.86	1400
23&24	215	14.98	580	40.42	640	44.60	1435
9&10	297	19.14	679	43.75	576	37.11	1552
Not Solved							
7	1242	64.99	382	19.99	287	15.02	1911
26&27	290	22.66	295	23.05	695	54.30	1280
5	281	48.36	150	25.82	150	25.82	581
21	617	42.00	194	13.21	658	44.79	1469
3	509	62.45	136	16.69	170	20.86	815
31	716	86.16	55	6.62	60	7.22	831
12	378	64.73	67	11.47	139	23.80	584
13	617	30.85	399	19.95	984	49.20	2000
4	108	25.00	274	63.43	50	11.57	432
2	274	47.40	204	35.29	100	17.30	578
25	507	70.03	217	29.97	0	0.00	724
14	249	73.45	90	26.55	0	0.00	339
22	520	82.80	108	17.20	0	0.00	628

Table 78 Raw Data from The Smuggling Scarecrow: NtTB

Table 79, see below, presents the raw data from The Smuggling Scarecrow attempts, regarding their 'Clarification', 'Encouragement' and 'Silence' activities.

The Smuggling Scarecrow							
Participant	**Clarification**	**%**	**Encouragement**	**%**	**Silence**	**%**	**Total Time**
11	0	0.00	0	0.00	241	100.0	241
6	90	21.38	0	0.00	331	78.62	421
1	131	20.89	120	19.1	376	59.97	627
17&18	101	38.90	0	0.00	424	61.10	694
15&16	57	33.22	56	6.35	533	60.43	882
28	92	10.34	152	17.1	646	72.58	890
29&30	270	72.67	0	0.00	299	27.33	1094
20	170	14.66	54	4.66	936	80.69	1160
19	260	19.97	206	15.8	836	64.21	1302
8	30	2.14	185	13.2	1185	84.64	1400
23&24	410	65.16	0	0.00	500	34.84	1435
9&10	264	52.06	43	2.77	701	45.17	1552
Not Solved							
7	178	9.31	123	6.44	1610	84.25	1911
26&27	253	68.83	0	0.00	399	31.17	1280
5	90	15.49	0	0.00	491	84.51	581
21	184	12.53	163	11.1	1122	76.38	1469
3	190	23.31	148	18.2	477	58.53	815
31	248	29.84	125	15.1	458	55.11	831
12	11	1.88	76	13.0	497	85.10	584
13	208	10.40	329	16.5	1463	73.15	2000
4	143	33.10	10	2.31	279	64.58	432
2	73	12.63	13	2.25	492	85.12	578
25	116	16.02	94	12.9	514	70.99	724
14	60	17.70	0	0.00	279	82.30	339
22	121	19.27	58	9.24	449	71.50	628

Table 79 Raw Data from The Smuggling Scarecrow: CES

A2 Statistical Analysis of the Data from Puzzle Solving Activities

A2.1 The Dalén Lamp NtTB & CES

The following tables (Tables 80-97) present the statistical analysis of the 3 puzzles in full.

Patterns in 'Not-Touching', 'Touching' and 'Building' for The Dalén Lamp					
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*
Not-Touching	9[34]	1557	173	22951.75	
Touching	9	5384	598.22	78971.19	
Building	9	1991	221.22	29475.19	

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	975805	2	487902.5	11.13948	0.000378	3.402826
Within Groups	1051185	24	43799.38			
Total	2026990	26				

Table 80 ANOVA Results for The Dalén Lamp NtTB

There was a statistically significant difference between the groups as determined by one-way ANOVA (F(2,24) = 11.139, p = .000378).

However, in these circumstances, it is best practice to perform a post-hoc test. The 3 groups were compared against each other.

Patterns in 'Not-Touching' and 'Touching' for The Dalén Lamp					
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*
Not-Touching	9	1557	173	22951.75	
Touching	9	5384	598.22	78971.19	

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	813662.7	1	813662.7	15.96623	0.001041	4.493998
Within Groups	815383.6	16	50961.47			
Total	1629046	17				

Table 81 ANOVA Post-hoc Results: Not-Touching & Touching for The Dalén Lamp

[34] 9 = 6 single participants and 3 pairs

Patterns in 'Touching' and 'Building' for The Dalén Lamp						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Touching	9	5384	598.22	78971.19		
Building	9	1991	221.22	29475.19		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	639580.5	1	639580.5	11.79533	0.003404	4.493998
Within Groups	867571.1	16	54223.19			
Total	1507152	17				

Table 82 ANOVA Post-hoc Results: Touching & Building for The Dalén Lamp

Patterns in 'Not-Touching' and 'Building' for The Dalén Lamp						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Not-Touching	9	1557	173	22951.75		
Building	9	1991	221.22	29475.19		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10464.22	1	10464.22	0.399193	0.53643	4.493998
Within Groups	419415.6	16	26213.47			
Total	429879.8	17				

Table 83 ANOVA Post-hoc Results: Not-Touching & Building for The Dalén Lamp

Patterns in 'Clarification', 'Encouragement' and 'Silence' for The Dalén Lamp						
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*	
Clarification	9	2925	325	78983.75		
Encouragement	9	460	51.11111	1711.611		
Silence	9	5547	616.3333	36999.75		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1438099	2	719049.6	18.32828	1.47E-05	3.402826
Within Groups	941560.9	24	39231.7			
Total	2379660	26				

Table 84 ANOVA Results for The Dalén Lamp CES

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(2,24) = 18.328$, $p = 1.47^{-5}$).

However, in these circumstances, it is best practice to perform a post-hoc test. The 3 groups were compared against each other.

Patterns in 'Clarification' and 'Encouragement' for The Dalén Lamp						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Clarification	9	2925	325	78983.75		
Encouragement	9	460	51.11111	1711.611		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	337568.1	1	337568.1	8.36648	0.010605	4.493998
Within Groups	645562.9	16	40347.68			
Total	983130.9	17				

Table 85 ANOVA Post-hoc Results: Clarification & Encouragement for The Dalén Lamp

Patterns in 'Encouragement' and 'Silence' for The Dalén Lamp						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Encouragement	9	460	51.11111	1711.611		
Silence	9	5547	616.3333	36999.75		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1437643	1	1437643	74.27498	2.08E-07	4.493998
Within Groups	309690.9	16	19355.68			
Total	1747334	17				

Table 86 ANOVA Post-hoc Results: Encouragement & Silence for The Dalén Lamp

Patterns in 'Clarification' and 'Silence' for The Dalén Lamp						
Groups	Count	Sum	Average	Variance	Sum, Average & Variance are in seconds.	
Clarification	9	2925	325	78983.75		
Silence	9	5547	616.3333	36999.75		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	381938	1	381938	6.586075	0.020707	4.493998
Within Groups	927868	16	57991.75			
Total	1309806	17				

Table 87 ANOVA Post-hoc Results: Clarification & Silence for The Dalén Lamp

There was a statistically significant difference between groups as determined by the one-way ANOVA ($F(2,24) = 18.328$, $p = 1.47^{-5}$).

A post-hoc test revealed that there remained a statistically significant difference between the:

1. 'Clarification' and 'Encouragement' grouping ($F(1,16) = 8.366$, $p = .010605$).
2. 'Encouragement' and 'Silence' grouping ($F(1,16) = 74.274$, $p = 2.08^{-7}$).
3. 'Clarification' and 'Silence' grouping ($F(1,16) = 6.586$, $p = 0.0207$).

A2.2 The Slow Elevator NtTB & CES

The ANOVA results of those that solved The Slow Elevator puzzle are as follows.

Patterns in 'Not-Touching', 'Touching' and 'Building' for The Slow Elevator						
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*	
Not-Touching	14[35]	5687	406.2143	49697.87		
Touching	14	3853	275.2143	20068.03		
Building	14	3964	283.1429	27190.13		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	151062	2	75531.02	2.33707	0.109998	3.238096
Within Groups	1260428	39	32318.68			
Total	1411490	41				

Table 88 ANOVA Results for The Slow Elevator NtTB

Here, as the calculated F value (2.034) is smaller than the F crit (3.24), the null hypothesis of "there are no statistical variances between 'Not-Touching', 'Touching' and 'Building'" cannot be rejected. The p-value (0.11) reinforces this.

Because of this result, there is no need for any post-hoc testing.

[35] 14 = 12 single participants and 2 pairs

The ANOVA results of those that solved The Slow Elevator puzzle were as follows:

'Clarification', 'Encouragement' and 'Silence' for The Slow Elevator						
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*	
Clarification	14	1913	136.6429	21005.79		
Encouragement	14	1144	81.71429	10184.68		
Silence	14	10448	746.2857	80129.6		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3809571	2	1904786	51.33268	1.19E-11	3.238096
Within Groups	1447161	39	37106.69			
Total	5256732	41				

Table 89 ANOVA Results: CES for The Slow Elevator

The calculated F value (51.33) is larger than the F crit (3.238), so I can reject the null hypothesis. The p-value (an extremely small 1.9^{-11}) reinforces this.

As "there are no statistical variances between 'Clarification', 'Encouragement' and 'Silence' in the 14 examples of those students who solved the Slow Elevator puzzle, the null hypothesis can be rejected.

However, in these circumstances, it is best practice to perform a post-hoc test. The 3 groups were compared against each other.

Patterns in 'Clarification' and 'Encouragement' for The Slow Elevator						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Clarification	14	1913	136.6429	21005.79		
Encouragement	14	1144	81.71429	10184.68		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21120.04	1	21120.04	1.354262	0.255103	4.225201
Within Groups	405476.1	26	15595.23			
Total	426596.1	27				

Table 90 ANOVA Post-hoc Results: Clarification & Encouragement for The Slow Elevator

Patterns in 'Encouragement' and 'Silence' for The Slow Elevator						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Encouragement	14	1144	81.71429	10184.68		
Silence	14	10448	746.2857	80129.6		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3091586	1	3091586	68.46284	9.35E-09	4.225201
Within Groups	1174086	26	45157.14			
Total	4265672	27				

Table 91 ANOVA Post-hoc Results: Encouragement & Silence for The Slow Elevator

Patterns in 'Clarification' and 'Silence' for The Slow Elevator						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Clarification	14	1913	136.6429	21005.79		
Silence	14	10448	746.2857	80129.6		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2601651	1	2601651	51.44887	1.29E-07	4.225201
Within Groups	1314760	26	50567.7			
Total	3916411	27				

Table 92 ANOVA Post-hoc Results: Clarification & Silence for The Slow Elevator

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(2,39) = 51.332$, $p = 1.19^{-11}$).

A post-hoc test revealed that there remained a statistically significant difference between the:

1. 'Encouragement' and 'Silence' grouping ($F(1,26) = 68.462$, $p = 9.35^{-9}$).
2. 'Clarification' and 'Silence' grouping ($F(1,26) = 51.448$, $p = 1.29^{-7}$).

However, there was no statistically significant difference between the 'Clarification' and 'Engagement' grouping ($F(1,16) = 1.354$, $p = 0.255$).

A2.3 The Smuggling Scarecrow NtTB & CES

The ANOVA results of those that solved The Slow Elevator puzzle were as follows:

Patterns in 'Not-Touching', 'Touching' and 'Building' for The Smuggling Scarecrow						
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*	
Not-Touching	12[36]	4472	372.6667	24423.15		
Touching	12	3625	302.0833	68866.45		
Building	12	3601	300.0833	43650.81		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	41017.39	2	20508.69	0.449291	0.641926	3.284918
Within Groups	1506345	33	45646.8			
Total	1547362	35				

Table 93 ANOVA Results for the Smuggling Scarecrow NtTB

As the calculated F value (.45) is smaller than the F crit (3.28), the null hypothesis cannot be rejected. The large p-value (0.64) reinforces this.

Because of this result, there is no need for any post-hoc testing.

The ANOVA results of those that solved The Smuggling Scarecrow puzzle were as follows:

'Clarification', 'Encouragement' and 'Silence' for The Smuggling Scarecrow						
Groups	**Count**	**Sum**	**Average**	**Variance**	*Sum, Average & Variance are in seconds.*	
Clarification	12	3674	306.1667	95102.88		
Encouragement	12	816	68	6052.545		
Silence	12	7008	584	82504.18		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1600683	2	800341.4	13.07323	6.59E-05	3.284918
Within Groups	2020256	33	61219.87			
Total	3620939	35				

Table 94 ANOVA Results for The Smuggling Scarecrow CES

[36] 12 = 7 single participants and 5 pairs

There was a statistically significant difference between the groups as determined by one-way ANOVA ($F(2,33) = 13.07$, $p = 6.59^{-5}$).

In general, if the calculated F value (13.07) is larger than the F crit (3.28), you can reject the null hypothesis, with the P-value reinforcing this.

As there are no statistical variances between 'Clarification', 'Encouragement' and 'Silence' in the 12 examples of those students who solved The Smuggling Scarecrow puzzle, the null hypothesis can be rejected.

However, in these circumstances, it is best practice to perform a post-hoc test. The 3 groups were compared against each other.

Patterns in 'Clarification' and 'Encouragement' for The Smuggling Scarecrow						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Clarification	12	3674	306.1667	95102.88		
Encouragement	12	816	68	6052.545		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	340340.2	1	340340.2	6.729054	0.016563	4.30095
Within Groups	1112710	22	50577.71			
Total	1453050	23				

Table 95 ANOVA Post-hoc Results: Clarification & Encouragement for The Smuggling Scarecrow

Patterns in 'Encouragement' and 'Silence' for The Smuggling Scarecrow						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Encouragement	12	816	68	6052.545		
Silence	12	7008	584	82504.18		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1597536	1	1597536	36.07938	4.8E-06	4.30095
Within Groups	974124	22	44278.36			
Total	2571660	23				

Table 96 ANOVA Post-hoc Results: Encouragement & Silence for The Smuggling Scarecrow

Patterns in ‘Clarification’ and ‘Silence’ for The Smuggling Scarecrow						
Groups	Count	Sum	Average	Variance	*Sum, Average & Variance are in seconds.*	
Clarification	12	3674	306.1667	95102.88		
Silence	12	7008	584	82504.18		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	463148.2	1	463148.2	5.215425	0.032403	4.30095
Within Groups	1953678	22	88803.53			
Total	2416826	23				

Table 97 ANOVA Post-hoc Results: Clarification & Silence for The Smuggling Scarecrow

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(2,33) = 13.07$, $p = 6.59^{-5}$).

A post-hoc test revealed that there remained a statistically significant difference between the:

1. ‘Clarification’ and ‘Engagement’ grouping ($F(1,22) = 6.729$, $p = 0.0165$).
2. ‘Encouragement’ and ‘Silence’ grouping ($F(1,22) = 36.079$, $p = 4.8^{-6}$).
3. ‘Clarification’ and ‘Silence’ grouping ($F(1,22) = 5.215$, $p = 0.032$).

A2.4 Participant Comparisons

The following raw data presents the participants in order of success and split between single participants and paired participants. The key is as follows; see Table 98, immediately below. As an example, these 3 single participants finished in 1st, 9th, & 10th positions, respectively. The abbreviations DL, SE, & SS stand for The Dalén Lamp, The Slow Elevator, & The Smuggling Scarecrow.

P1's successful solve of The Dalén Lamp was the 6th fastest, her solve of The Slow Elevator was the 7th fastest, and her solve of The Smuggling Scarecrow was the 3rd fastest. While working on The Dalén Lamp, she spent 238 seconds 'Not-Touching', etc. P28 solved 2 puzzles. Her solve of The Smuggling Scarecrow was the 4th fastest. Her solve of The Slow Elevator was the 12th fastest. She did not solve The Dalén Lamp, but her effort was subjectively judged as being the 17th best attempt (out of 18). She was the bottom ranked of those who solved 2 puzzles. P2 solved 1 puzzle, but despite a fine overall performance, he places below her by default.

1	ID		NOT-TOUCHING	TOUCHING	BUILDING	Solved?
6	P1	DL	238	690	90	✓
7	P1	SE	310	230	170	✓
3	P1	SS	517	66	44	✓
9	ID		NOT-TOUCHING	TOUCHING	BUILDING	
17	P28	DL	201	14	0	X
12	P28	SE	663	517	415	✓
4	P28	SS	451	91	348	✓
10	ID		NOT-TOUCHING	TOUCHING	BUILDING	
9	P2	DL	377	726	395	X
1	P2	SE	161	64	207	✓
16	P2	SS	274	204	100	X

Table 98 Example of Participant Breakdown: NtTB

Table 99, see below, presents the single participants in order of success, with their 'Not-Touching', 'Touching' and 'Building' activities.

1	ID		NOT-TOUCHING	TOUCHING	BUILDING	Solved?
6	P1	DL	238	690	90	✓
7	P1	SE	310	230	170	✓
3	P1	SS	517	66	44	✓
2	ID		NOT-TOUCHING	TOUCHING	BUILDING	
4	P20	DL	78	571	286	✓
4	P20	SE	87	392	126	✓
5	P20	SS	265	563	332	✓
3	ID		NOT-TOUCHING	TOUCHING	BUILDING	
1	P21	DL	167	195	266	✓
2	P21	SE	118	331	154	✓
10	P21	SS	617	194	658	X
4	ID		NOT-TOUCHING	TOUCHING	BUILDING	
8	P11	DL	186	350	955	X
7	P11	SE	401	37	530	✓
1	P11	SS	176	38	27	✓
5	ID		NOT-TOUCHING	TOUCHING	BUILDING	
7	P5	DL	158	780	390	✓
6	P5	SE	296	270	225	✓
9	P5	SS	281	150	150	X

6	ID		NOT-TOUCHING	TOUCHING	BUILDING	
2	P31	DL	148	420	150	✓
8	P31	SE	521	150	360	✓
12	P31	SS	716	55	60	X
7	ID		NOT-TOUCHING	TOUCHING	BUILDING	Solved?
13	P8	DL	69	598	29	X
3	P8	SE	396	82	126	✓
7	P8	SS	445	425	530	✓
8			NOT-TOUCHING	TOUCHING	BUILDING	
3	P19	DL	188	598	37	✓
15	P19	SE	331	161	83	X
6	P19	SS	709	197	396	✓
9	ID		NOT-TOUCHING	TOUCHING	BUILDING	
17	P28	DL	201	14	0	X
12	P28	SE	663	517	415	✓
4	P28	SS	451	91	348	✓
10	ID		NOT-TOUCHING	TOUCHING	BUILDING	
9	P2	DL	377	726	395	X
1	P2	SE	161	64	207	✓
16	P2	SS	274	204	100	X
11	ID		NOT-TOUCHING	TOUCHING	BUILDING	
5	P12	DL	548	277	155	X
9	P12	SE	503	398	135	✓
13	P12	SS	378	67	139	X

12	ID		NOT-TOUCHING	TOUCHING	BUILDING	
12	P6	DL	185	400	15	X
18	P6	SE	686	873	0	X
2	P6	SS	331	15	75	✓
13	ID		NOT-TOUCHING	TOUCHING	BUILDING	Solved?
11	P25	DL	220	340	0	X
11	P25	SE	896	298	222	✓
17	P25	SS	507	217	0	X
14	ID		NOT-TOUCHING	TOUCHING	BUILDING	
15	P14	DL	451	760	0	X
10	P14	SE	324	465	361	✓
18	P14	SS	249	90	0	X
15	ID		NOT-TOUCHING	TOUCHING	BUILDING	
12	P3	DL	588	338	246	X
16	P3	SE	616	97	0	X
11	P3	SS	509	136	170	X
16	ID		NOT-TOUCHING	TOUCHING	BUILDING	
16	P4	DL	609	63	0	X
14	P4	SE	511	488	597	X
15	P4	SS	108	274	50	X

17	ID		NOT-TOUCHING	TOUCHING	BUILDING	
18	P7	DL	180	600	0	X
19	P7	SE	9	0	0	X
8	P7	SS	1242	382	287	X
18	ID		NOT-TOUCHING	TOUCHING	BUILDING	Solved?
14	P22	DL	142	1060	0	X
13	P22	SE	243	317	310	X
19	P22	SS	520	108	0	X
19	ID		NOT-TOUCHING	TOUCHING	BUILDING	
19	P13	DL	NOT ATTEMPTED			
17	P13	SE	485	215	0	X
14	P13	SS	617	399	984	X

Table 99 Participant Breakdown: NtTB

Table 100, see below, presents the single participants in order of success, with their 'Clarification', 'Encouragement' and 'Silence' activities.

1	ID		Clarification	Encouragement	Silence	Solved?
6	P1	DL	67	96	772	✓
7	P1	SE	8	48	549	✓
3	P1	SS	170	54	936	✓
2	ID		Clarification	Encouragement	Silence	
4	P20	DL	230	80	708	✓
4	P20	SE	165	0	545	✓
5	P20	SS	131	120	376	✓
3	ID		Clarification	Encouragement	Silence	
1	P21	DL	86	24	518	✓
2	P21	SE	37	59	507	✓
10	P21	SS	184	163	1122	X
4	ID		Clarification	Encouragement	Silence	Solved?
8	P11	DL	139	85	1267	X
7	P11	SE	179	18	771	✓
1	P11	SS	0	0	241	✓
5	ID		Clarification	Encouragement	Silence	
7	P5	DL	290	15	1023	✓
6	P5	SE	167	0	624	✓
9	P5	SS	90	0	491	X
6	ID		Clarification	Encouragement	Silence	
2	P31	DL	150	105	463	✓
8	P31	SE	95	150	786	✓
12	P31	SS	248	125	458	X

7	ID		Clarification	Encouragement	Silence	
13	P8	DL	64	12	620	X
3	P8	SE	0	38	566	✓
7	P8	SS	30	185	1185	✓
8			Clarification	Encouragement	Silence	
3	P19	DL	185	94	544	✓
15	P19	SE	26	102	447	X
6	P19	SS	260	206	836	✓
9	ID		Clarification	Encouragement	Silence	
17	P28	DL	12	19	184	X
12	P28	SE	5	241	1349	✓
4	P28	SS	92	152	646	✓
10	ID		Clarification	Encouragement	Silence	Solved?
9	P2	DL	183	164	1151	X
1	P2	SE	50	17	365	✓
16	P2	SS	73	13	492	X
11	ID		Clarification	Encouragement	Silence	
5	P12	DL	57	104	819	X
9	P12	SE	35	132	869	✓
13	P12	SS	11	76	497	X
12	ID		Clarification	Encouragement	Silence	
12	P6	DL	240	45	315	X
18	P6	SE	375	240	944	X
2	P6	SS	90	0	331	✓

13	ID		Clarification	Encouragement	Silence	
11	P25	DL	30	83	447	X
11	P25	SE	209	337	870	✓
17	P25	SS	116	94	514	X
14	ID		Clarification	Encouragement	Silence	
15	P14	DL	260	30	921	X
10	P14	SE	90	75	985	✓
18	P14	SS	60	0	279	X
15	ID		Clarification	Encouragement	Silence	
12	P3	DL	65	81	1026	X
16	P3	SE	141	180	392	X
11	P3	SS	190	148	477	X
16	ID		Clarification	Encouragement	Silence	Solved?
16	P4	DL	59	65	548	X
14	P4	SE	257	155	1184	X
15	P4	SS	143	10	279	X
17	ID		Clarification	Encouragement	Silence	
18	P7	DL	106	192	482	X
19	P7	SE	0	0	9	X
8	P7	SS	178	123	1610	X
18	ID		Clarification	Encouragement	Silence	
14	P22	DL	136	221	845	X
13	P22	SE	47	120	703	X
19	P22	SS	121	58	449	X

19	ID		Clarification	Encouragement	Silence	
19	P13	DL	NOT ATTEMPTED			
17	P13	SE	117	240	343	X
14	P13	SS	208	329	1463	X

Table 100 Participant Breakdown: CES

Table 101, see below, presents the paired participants in order of success.

1	ID		NOT-TOUCHING	TOUCHING	BUILDING	Solved?
	P17&P18	DL	152	450	173	✓
	P17&P18	SE	132	775	314	X
	P17&P18	SS	456	108	140	✓
2	ID		NOT-TOUCHING	TOUCHING	BUILDING	
	P15&P16	DL	120	489	251	X
	P15&P16	SE	293	353	312	✓
	P15&P16	SS	416	198	268	✓
3	ID		NOT-TOUCHING	TOUCHING	BUILDING	
	P29&P30	DL	Not Attempted			X
	P29&P30	SE	671	245	690	✓
	P29&P30	SS	456	98	140	✓
4	ID		NOT-TOUCHING	TOUCHING	BUILDING	
	P23&P24	DL	49	1170	45	✓
	P23&P24	SE	Not Attempted			X
	P23&P24	SS	215	580	640	✓
5	ID		NOT-TOUCHING	TOUCHING	BUILDING	

	P9&P10	DL	198	925	0	X
	P9&P10	SE	Not Attempted			X
	P9&P10	SS	297	679	576	✓
6	ID		NOT-TOUCHING	TOUCHING	BUILDING	
	P26&P27	DL	527	338	555	✓
	P26&P27	SE	Not Attempted			X
	P26&P27	SS	290	295	695	X

Table 101 Paired Participant Breakdown: NtTB

Table 102, see below, presents the paired participants in order of success, with their 'Clarification', 'Encouragement' and 'Silence' activities.

1	ID		Clarification (Facilitator)	Encouragement (Facilitator)	Silence	Clarification (each other)
	P17&P18	DL	198	26	404	170
	P17&P18	SE	60	64	835	249
	P17&P18	SS	101	0	424	169
2	ID		Clarification (Facilitator)	Encouragement (Facilitator)	Silence	Clarification (each other)
	P15&P16	DL	103	5	468	284
	P15&P16	SE	104	29	481	344
	P15&P16	SS	57	56	533	236
3	ID		Clarification (Facilitator)	Encouragement (Facilitator)	Silence	Clarification (each other)
	P29&P30	DL	Not Attempted			
	P29&P30	SE	180	180	1001	245
	P29&P30	SS	101	0	424	169

4	ID		Clarification (Facilitator)	Encouragement (Facilitator)	Silence	Clarification (each other)
	P23&P24	DL	265	15	619	365
	P23&P24	SE	Not Attempted			
	P23&P24	SS	410	0	500	525
5	ID		Clarification (Facilitator)	Encouragement (Facilitator)	Silence	Clarification (each other)
	P9&P10	DL	154	101	540	328
	P9&P10	SE	Not Attempted			
	P9&P10	SS	264	43	701	544
6	ID		Clarification (Facilitator)	Encouragement (Facilitator)	Silence	Clarification (each other)
	P26&P27	DL	156	5	496	763
	P26&P27	SE	Not Attempted			
	P26&P27	SS	253	0	399	628

Table 102 Paired Participant Breakdown: CES

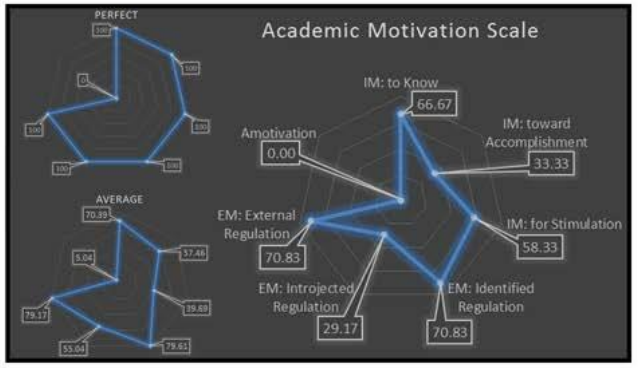
A3 Individual Timelines

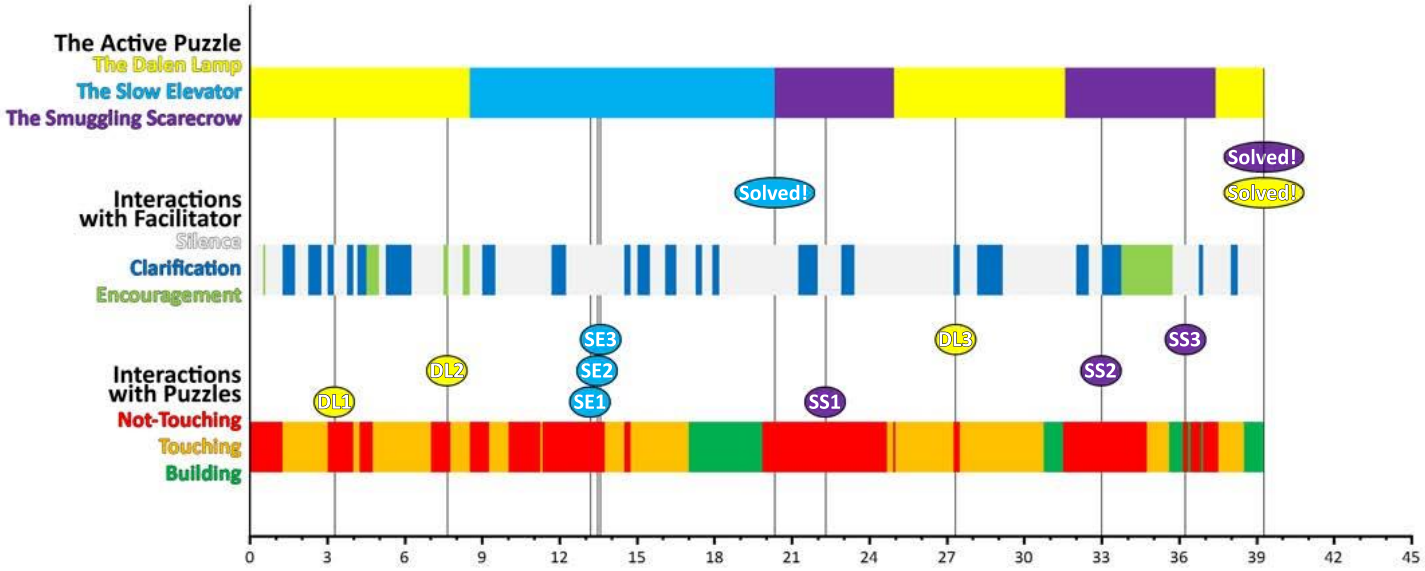
The Individual Timelines for each participant are now presented.

Participant 01: Female; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **23rd** (shared)
Extrinsic Motivation: **28th** (shared)
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **6th**
The Slow Elevator: **5th**
The Smuggling Scarecrow: **3rd**
Overall Placement: **2nd**

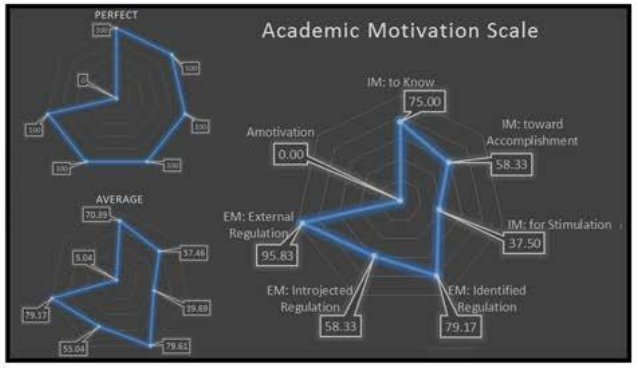


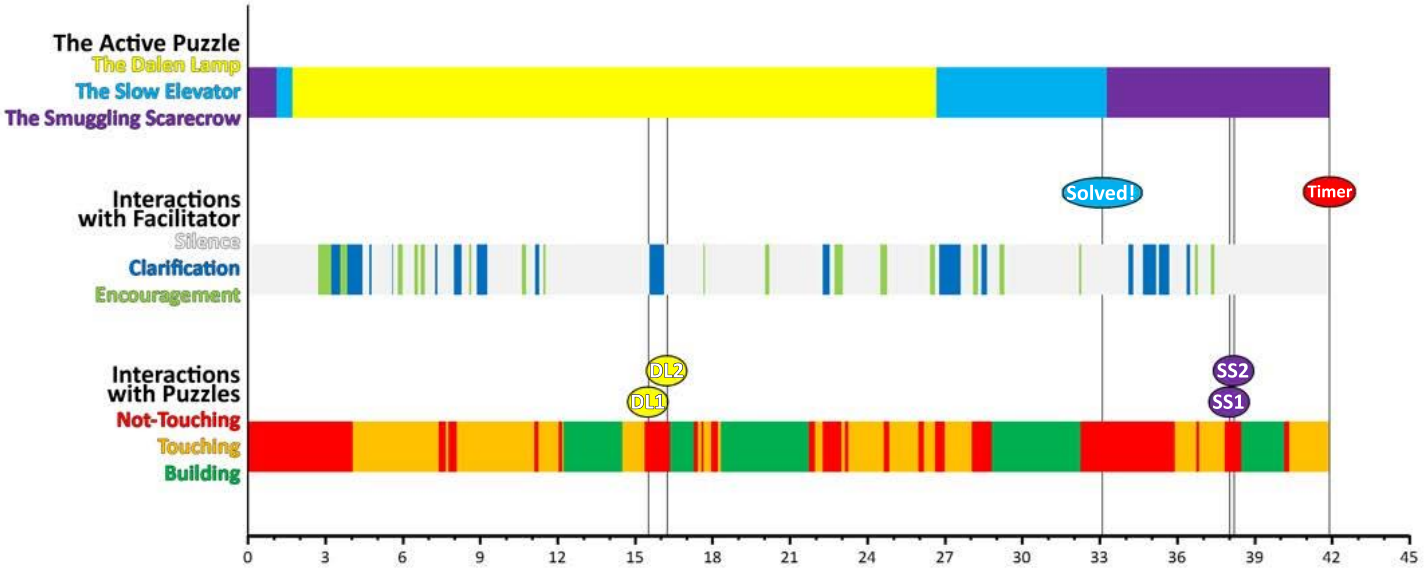


Participant 02: Male; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **19th**
Extrinsic Motivation: **13th**
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **9th**
The Slow Elevator: **1st**
The Smuggling Scarecrow: **16th**
Overall Placement: **10th**

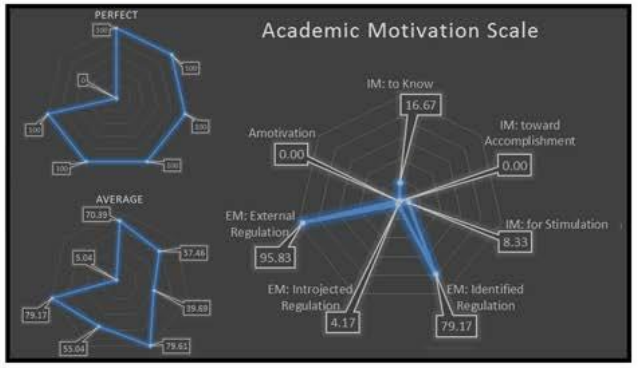


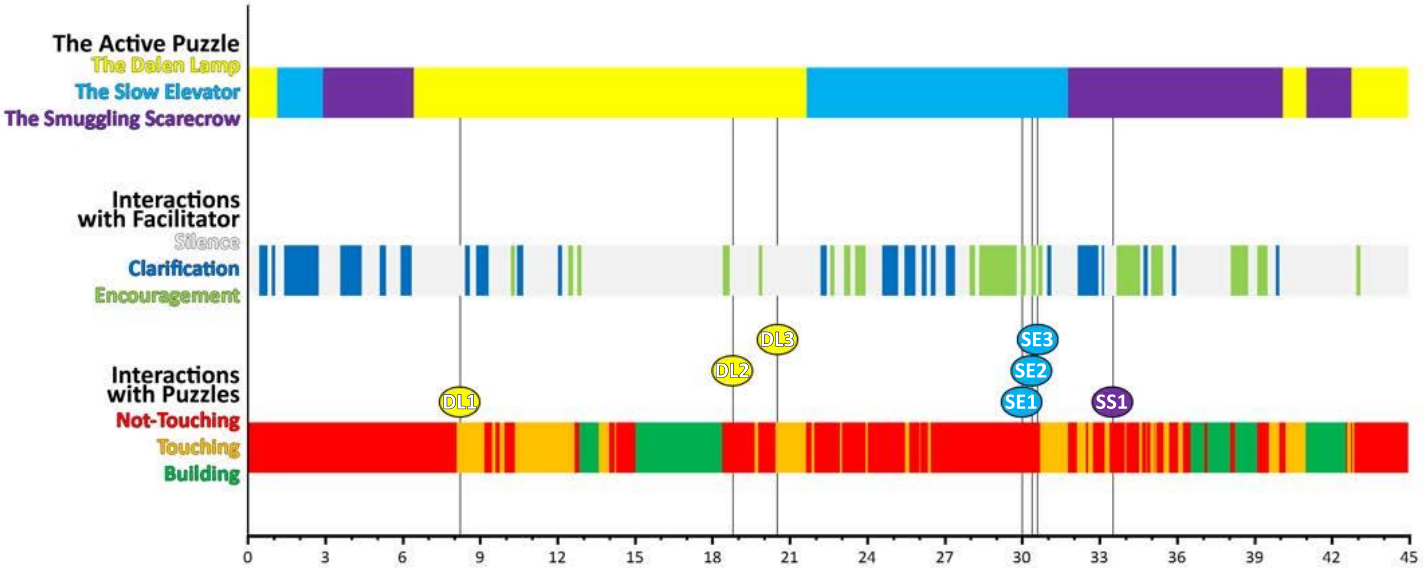


Participant 03: Female; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **31st**
Extrinsic Motivation: **25th** (shared)
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **10th**
The Slow Elevator: **16th**
The Smuggling Scarecrow: **11th**
Overall Placement: **15th** (shared)

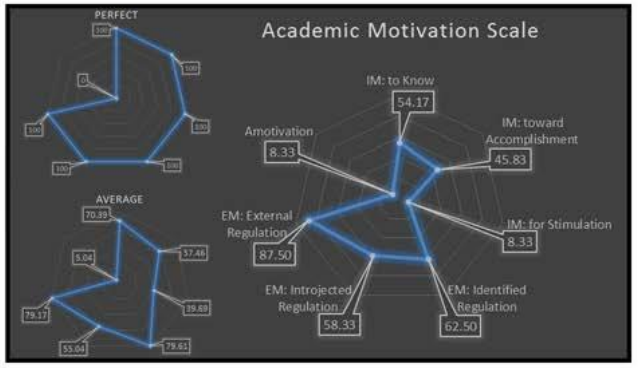


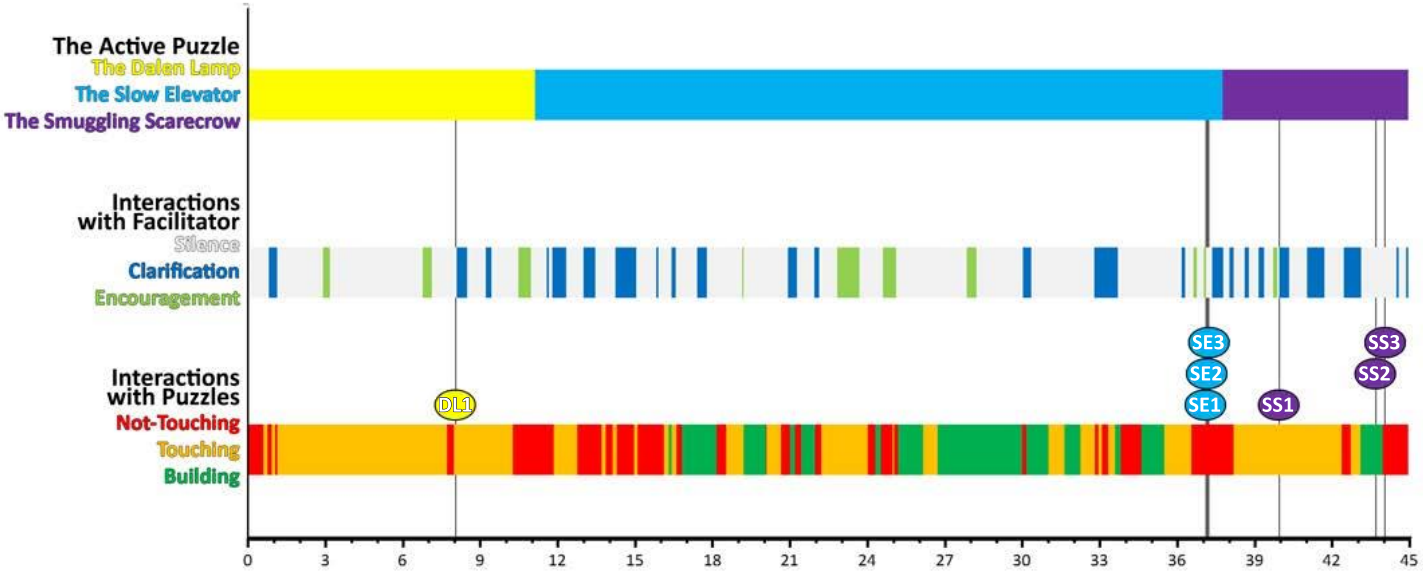


Participant 04: Male; 1st Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **28th**
Extrinsic Motivation: **19th** (shared)
Amotivation: **8th** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **16th**
The Slow Elevator: **14th**
The Smuggling Scarecrow: **15th**
Overall Placement: **15th** (shared)

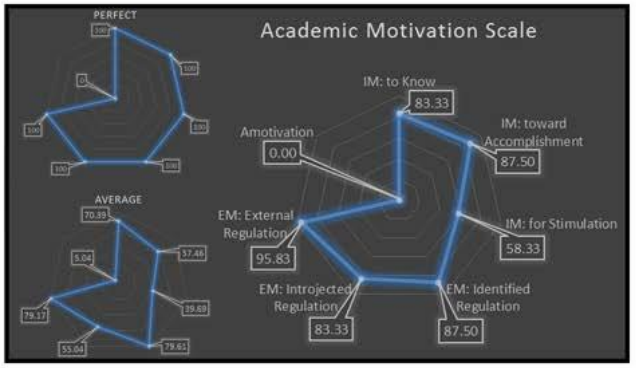


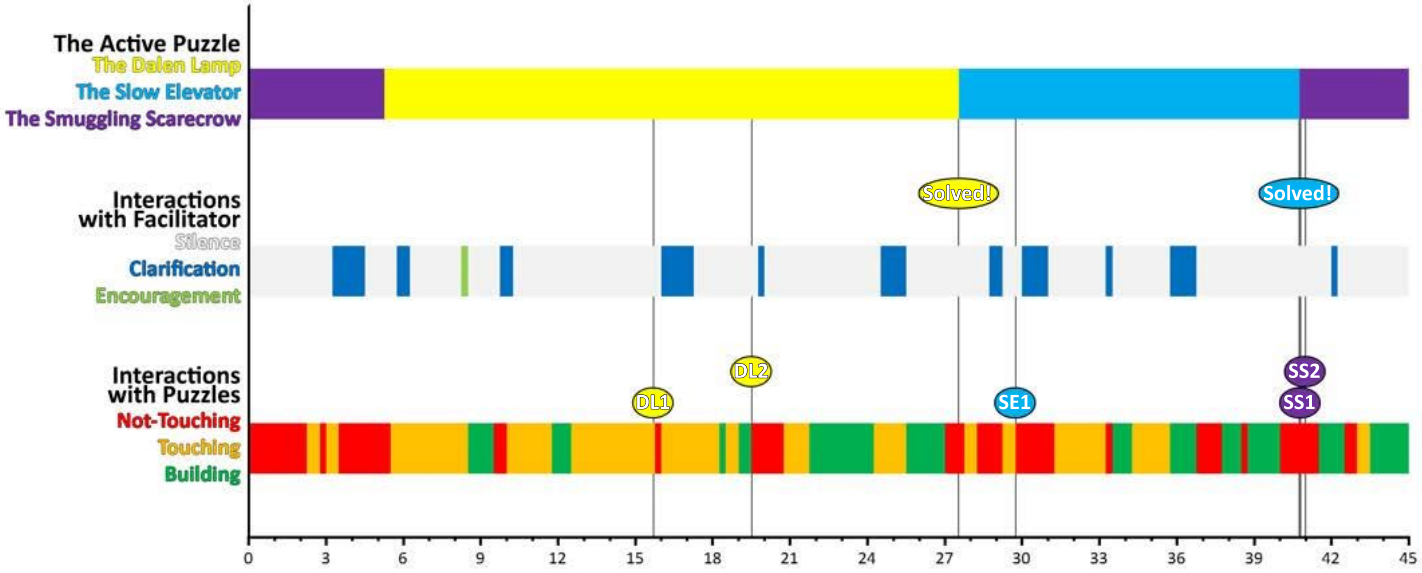


Participant 05: Female; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **4th** (shared)
Extrinsic Motivation: **3rd** (shared)
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **7th**
The Slow Elevator: **6th**
The Smuggling Scarecrow: **9th**
Overall Placement: **5th** (shared)

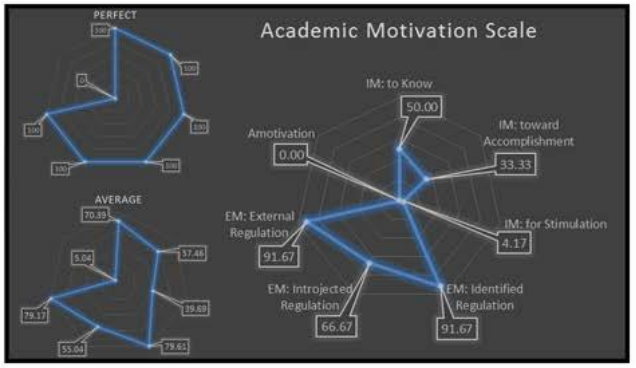


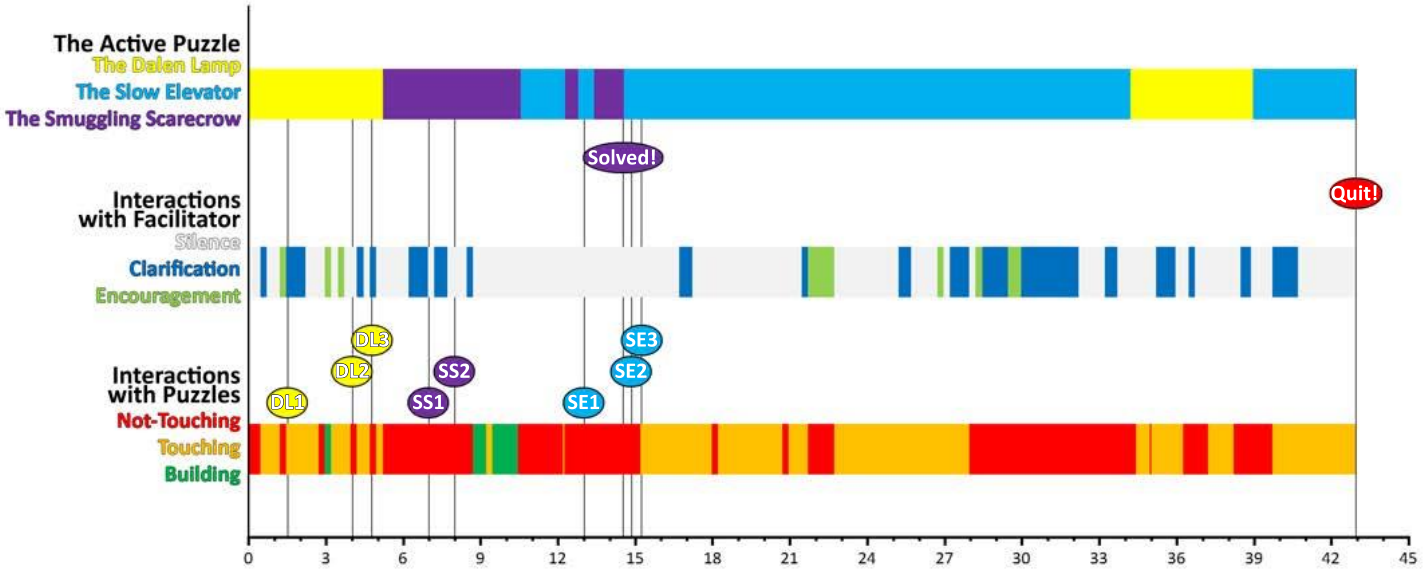


Participant 06: Female; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **30th**
Extrinsic Motivation: **6th** (shared)
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **12th**
The Slow Elevator: **18th**
The Smuggling Scarecrow: **2nd**
Overall Placement: **12th**

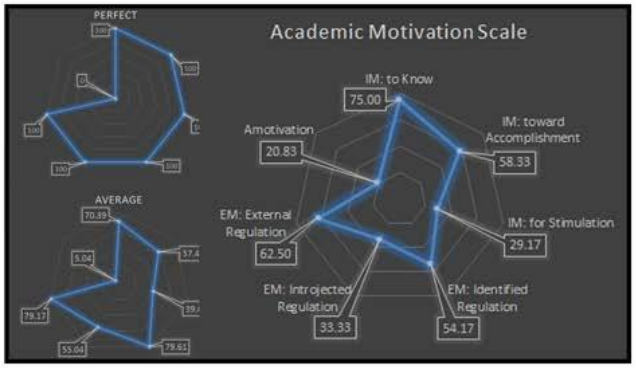


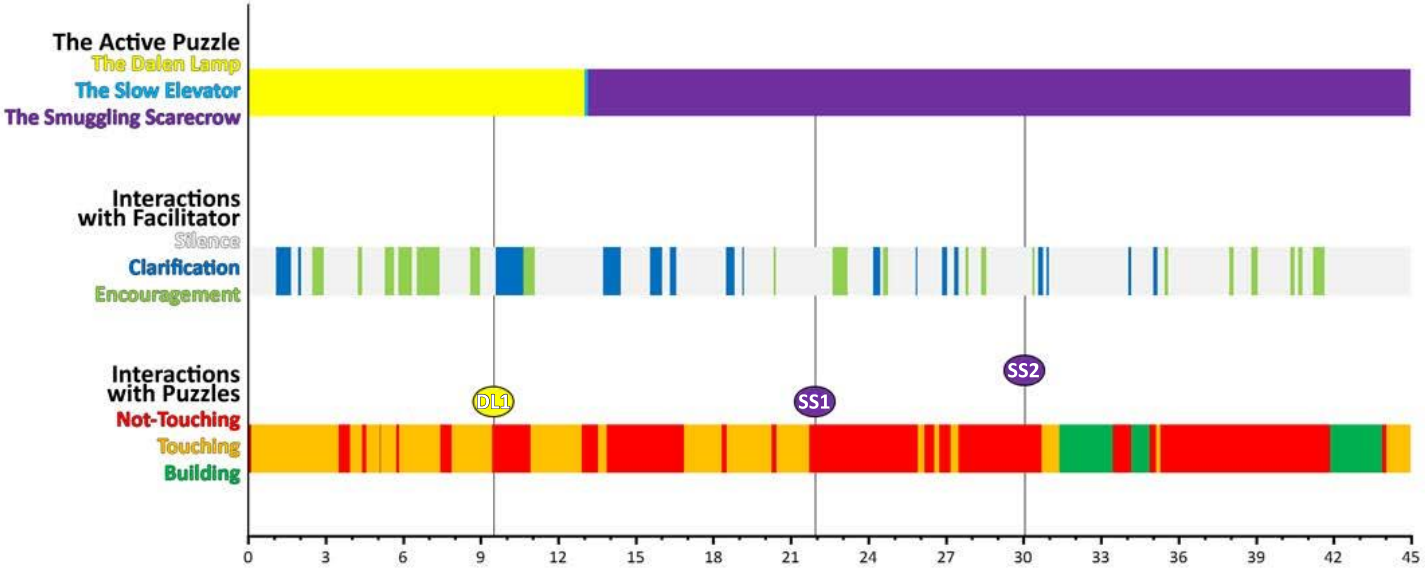


Participant 07: Male; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **20th** (shared)
Extrinsic Motivation: **31st**
Amotivation: **4th** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **18th**
The Slow Elevator: **19th**
The Smuggling Scarecrow: **8th**
Overall Placement: **17th**

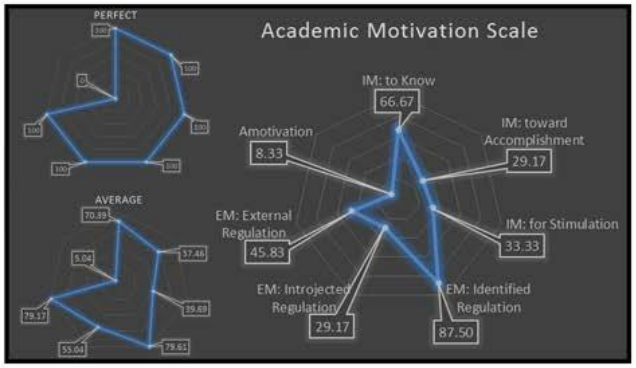


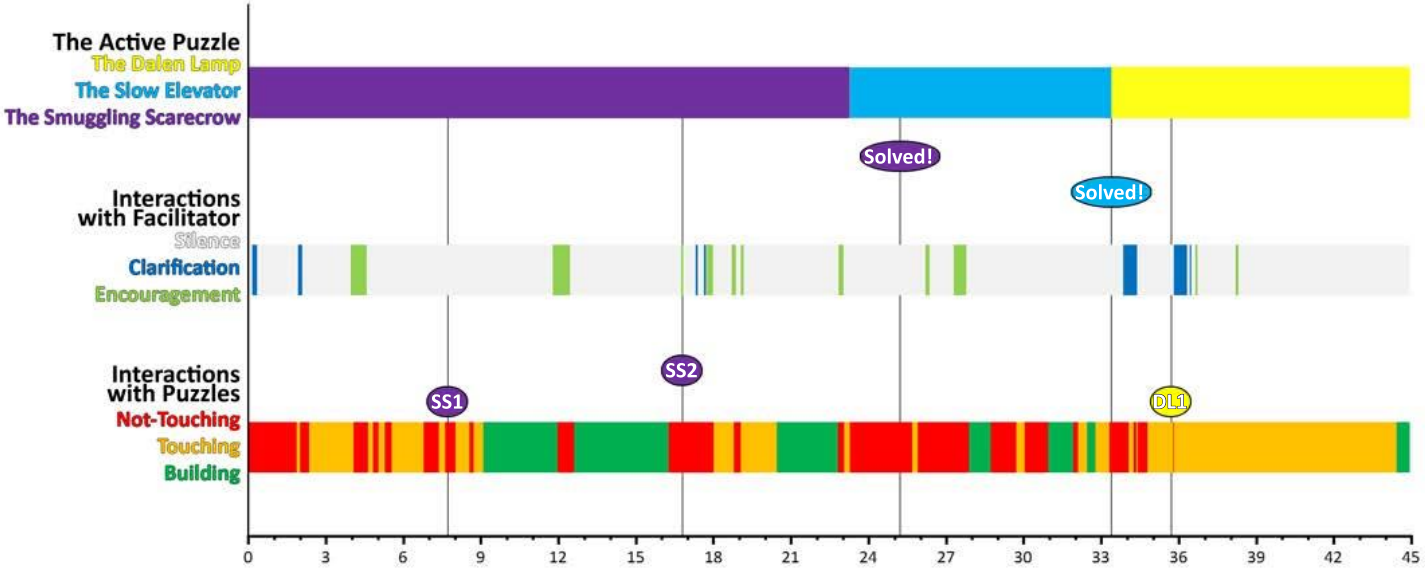


Participant 08: Male; 1st Year

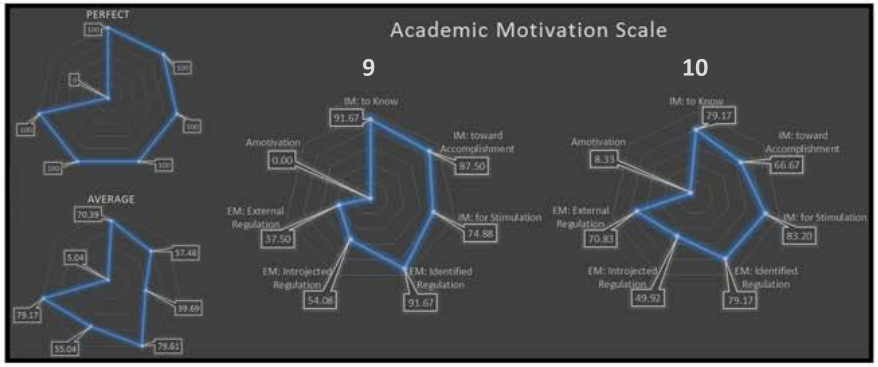
Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **26th**
Extrinsic Motivation: **30th**
Amotivation: **8th** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **13th**
The Slow Elevator: **3rd**
The Smuggling Scarecrow: **7th**
Overall Placement: **7th**





Participant 09: Female; Masters
Participant 10: Female; Masters

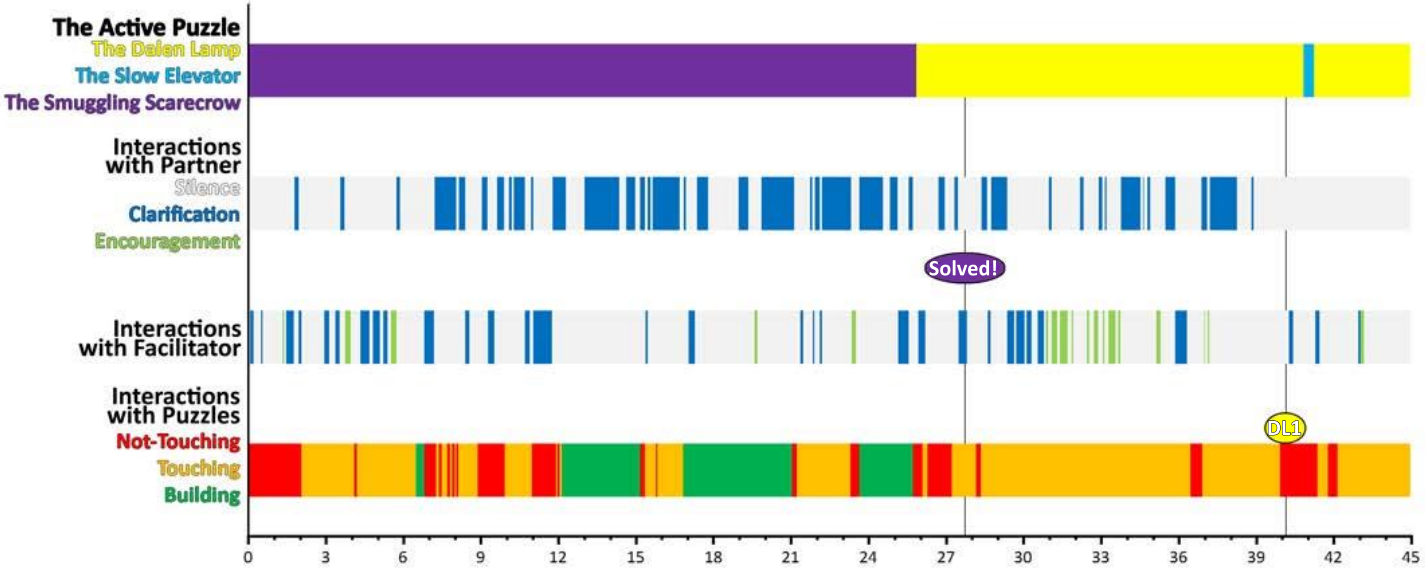


Academic Motivation Scale (from 1st to 31st)

	P9	P10
Intrinisic Motivation:	**1st**	**7th**
Extrinsic Motivation:	**23rd** (shared)	**21st**
Amotivation:	**31st** (shared)	**8th** (shared)

Puzzle Performances (from 1st to 6th)

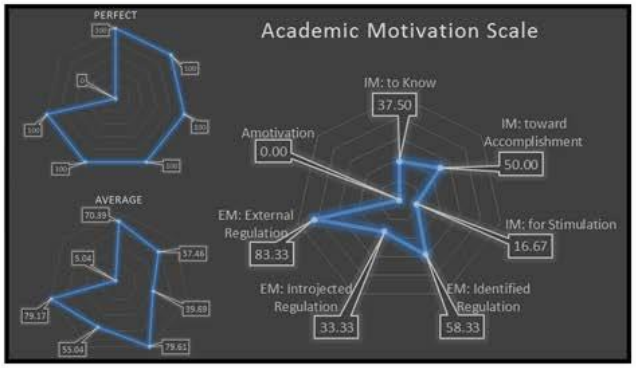
The Dalen Lamp:	**5th**
The Slow Elevator:	**6th**
The Smuggling Scarecrow:	**5th**
Overall Placement:	**5th**

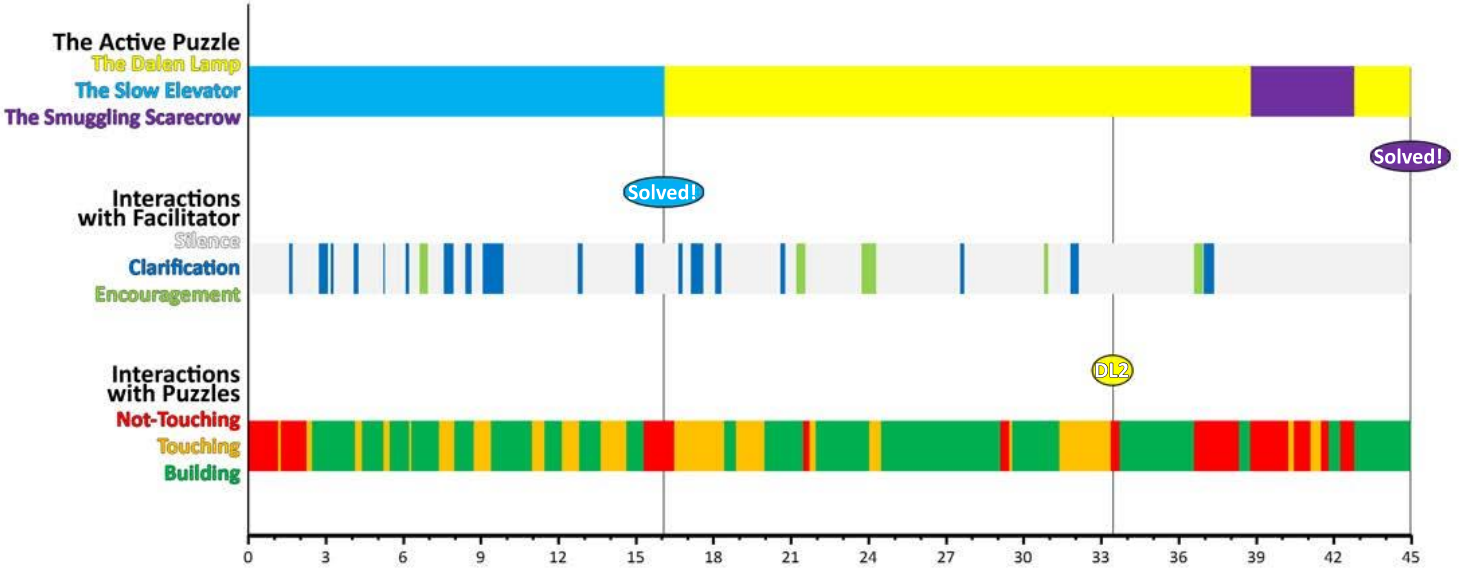


Participant 11: Male; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **29th**
Extrinsic Motivation: **27th**
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **8th**
The Slow Elevator: **7th**
The Smuggling Scarecrow: **1st**
Overall Placement: **4th**

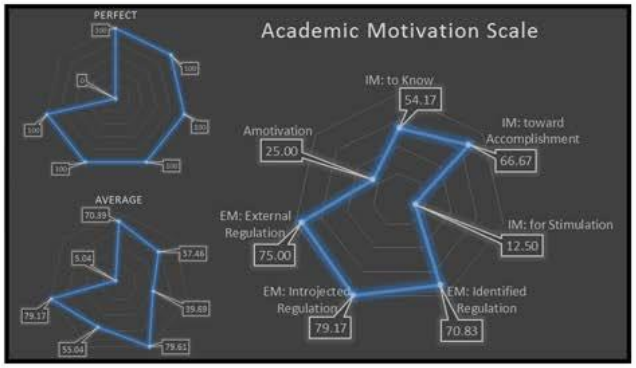


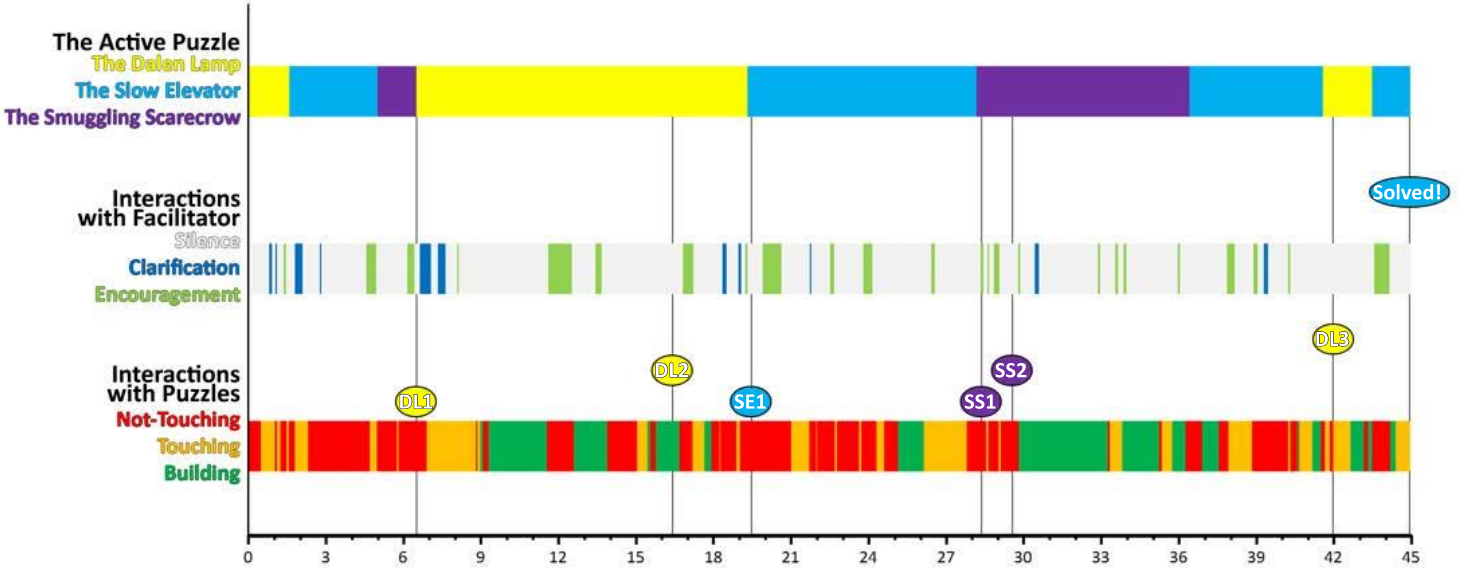


Participant 12: Male; Masters

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **25th**
Extrinsic Motivation: **15th**
Amotivation: **3rd**

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **5th**
The Slow Elevator: **9th**
The Smuggling Scarecrow: **13th**
Overall Placement: **11th**

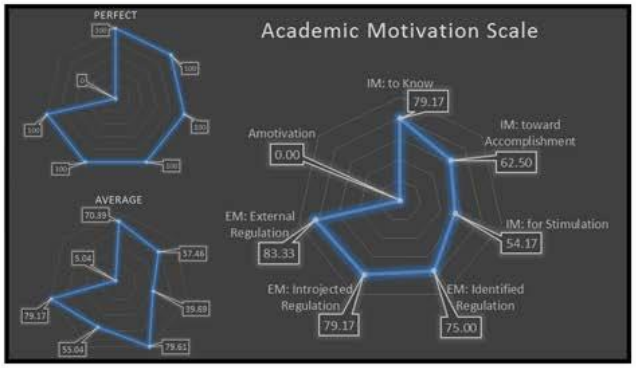


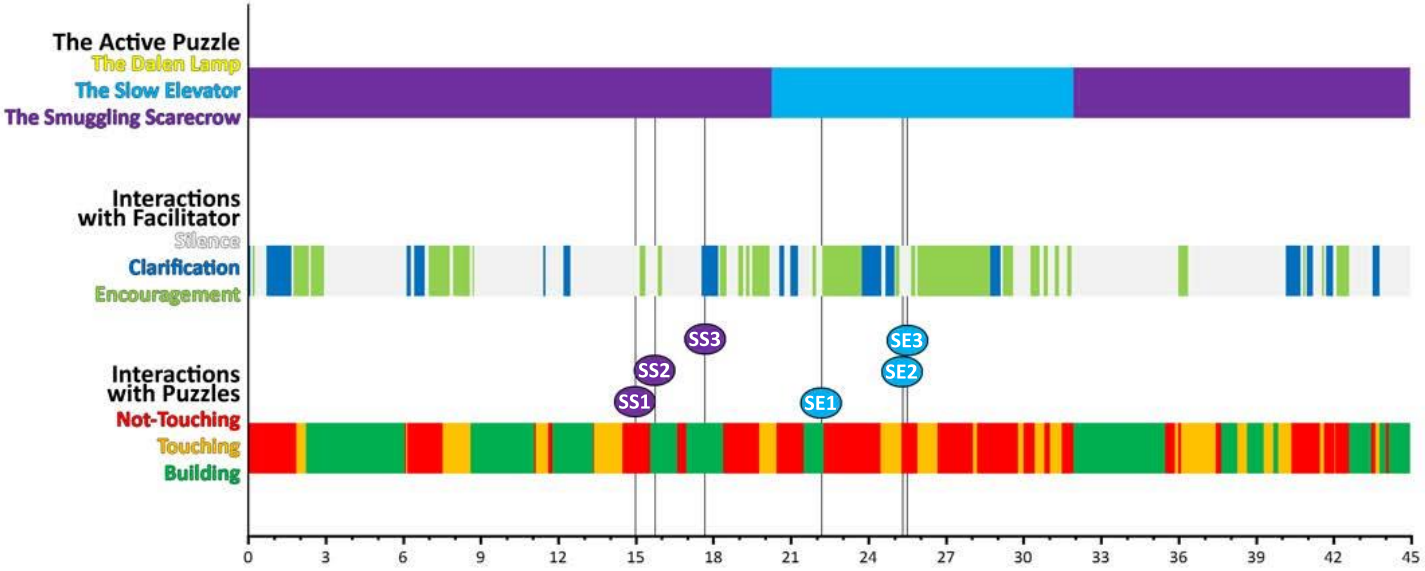


Participant 13: Male; 1st Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **12th** (shared)
Extrinsic Motivation: **11th** (shared)
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **19th**
The Slow Elevator: **17th**
The Smuggling Scarecrow: **14th**
Overall Placement: **19th**

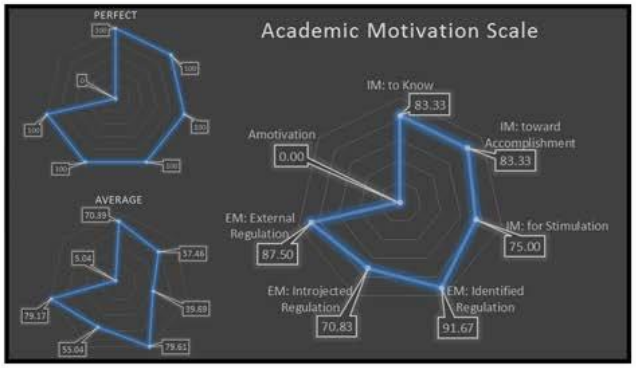


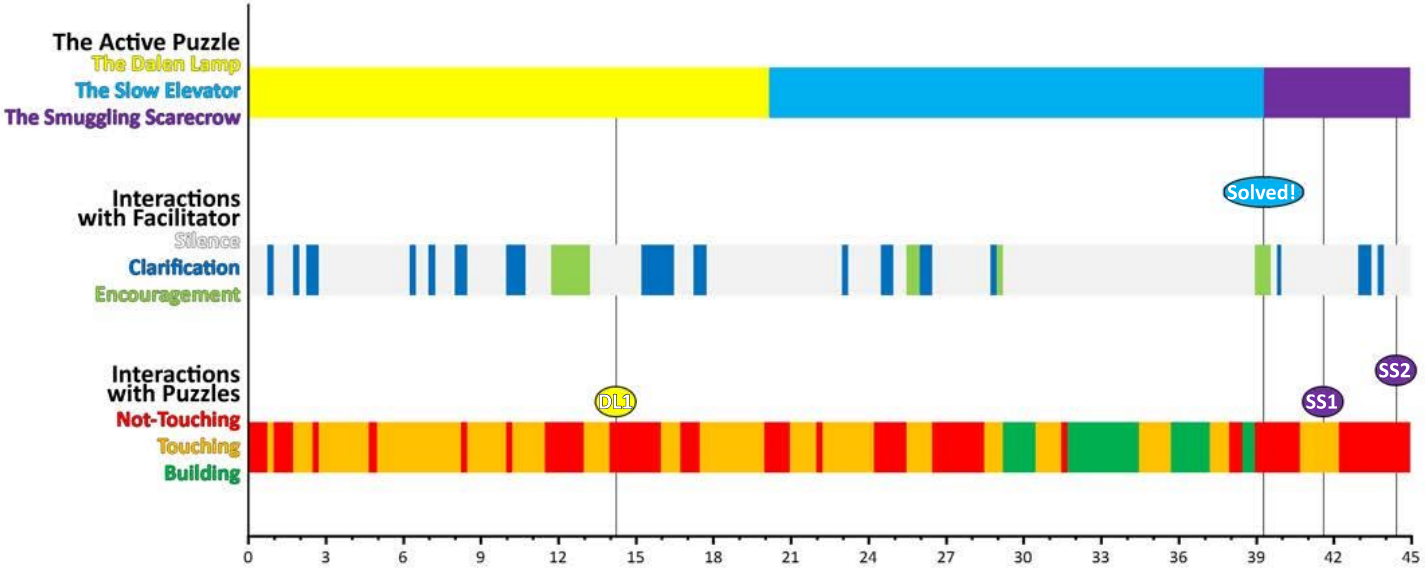


Participant 14: Male; 3rd Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **3rd**
Extrinsic Motivation: **6th**
Amotivation: **31st**

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **15th**
The Slow Elevator: **11th**
The Smuggling Scarecrow: **18th**
Overall Placement: **14th**

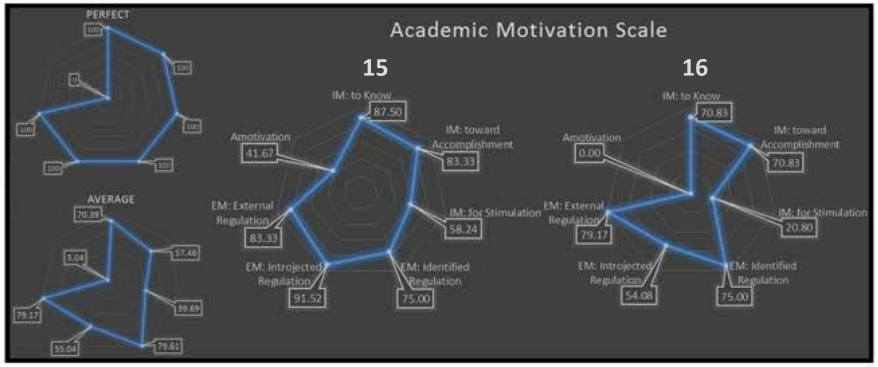




Participant 15: Male; 4th Year
Participant 16: Female; 4th Year

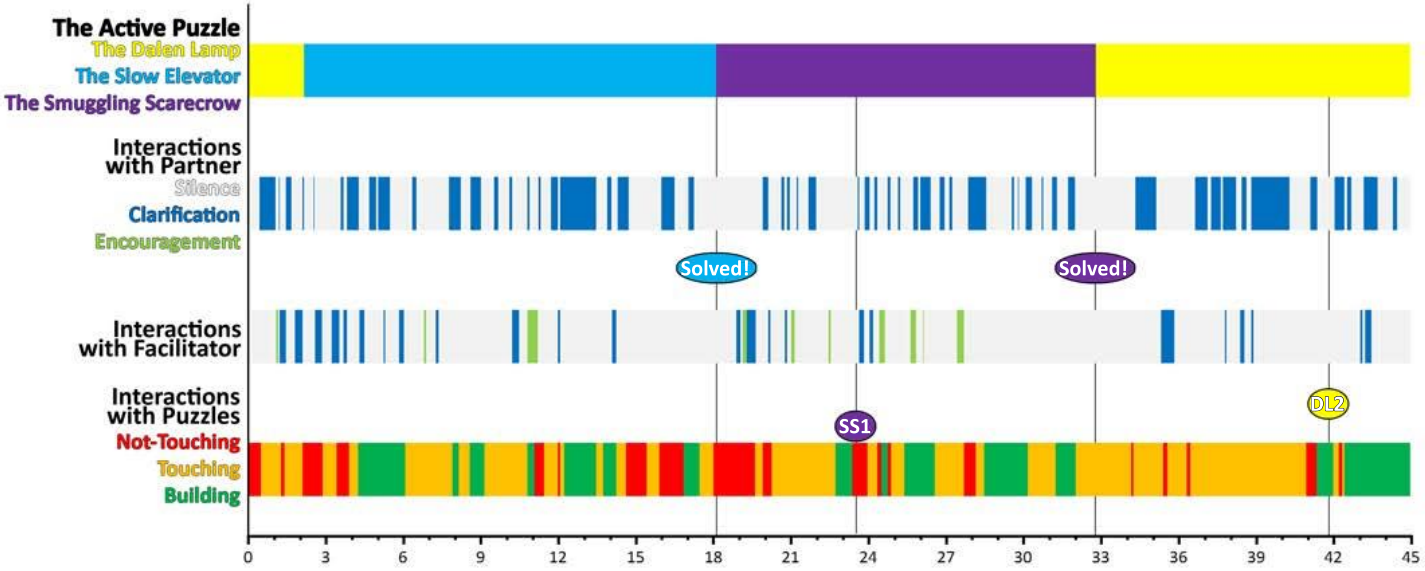
Academic Motivation Scale (from 1st to 31st)

	P15	P16
Intrinisic Motivation:	**4th** (shared)	**12th** (shared)
Extrinsic Motivation:	**6th** (shared)	**19th** (shared)
Amotivation:	**1st**	**31st** (shared)



Puzzle Performances (from 1st to 6th)

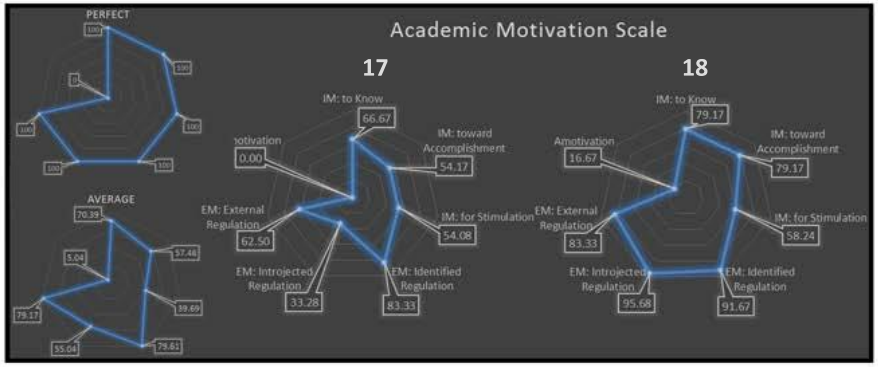
The Dalen Lamp:	**4th**
The Slow Elevator:	**1st**
The Smuggling Scarecrow:	**2nd**
Overall Placement:	**2nd**



Participant 17: Female; 3rd Year
Participant 18: Female; 3rd Year

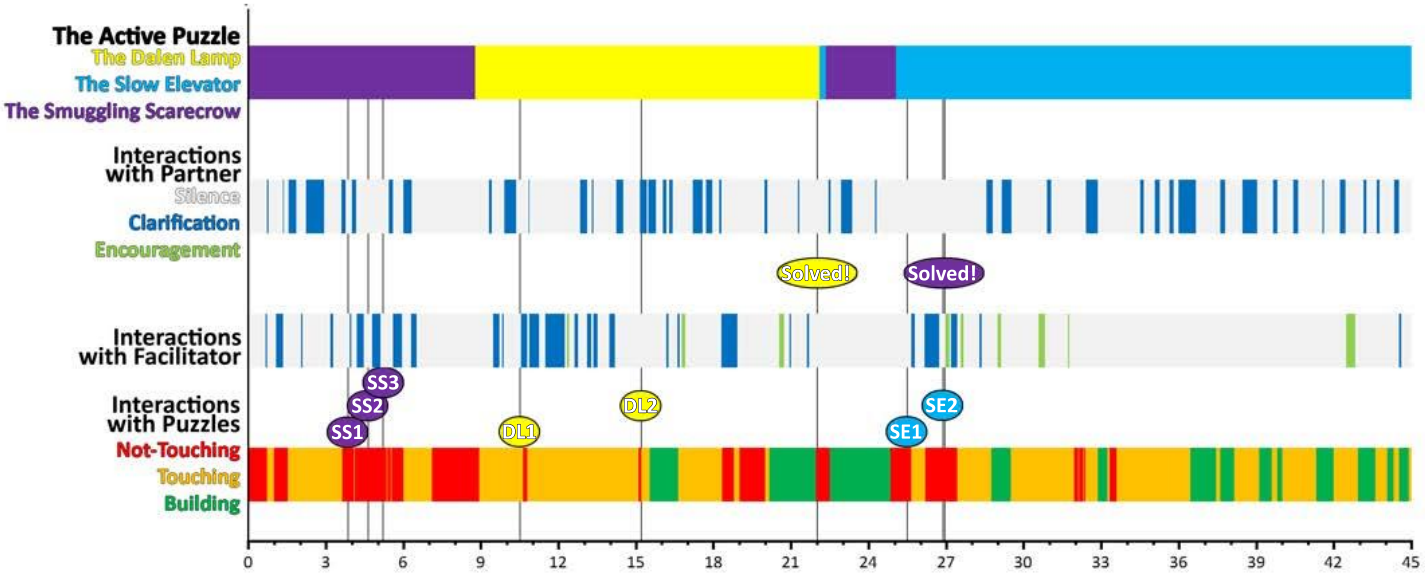
Academic Motivation Scale (from 1st to 31st)

	P17	P18
Intrinisic Motivation:	**18th**	**8th** (shared)
Extrinsic Motivation:	**25th** (shared)	**1st** (shared)
Amotivation:	**31st** (shared)	**6th** (shared)



Puzzle Performances (from 1st to 6th)

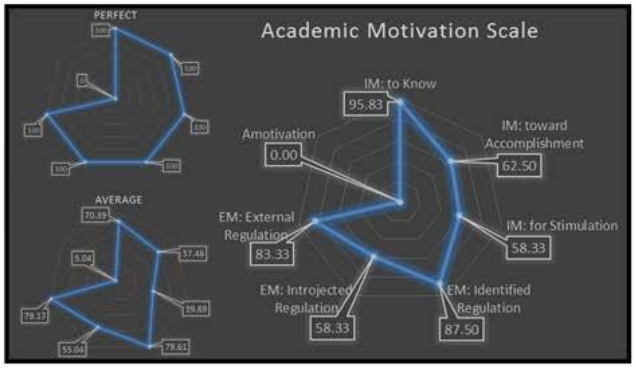
The Dalen Lamp:	**1st**
The Slow Elevator:	**3rd**
The Smuggling Scarecrow:	**1st**
Overall Placement:	**1st**

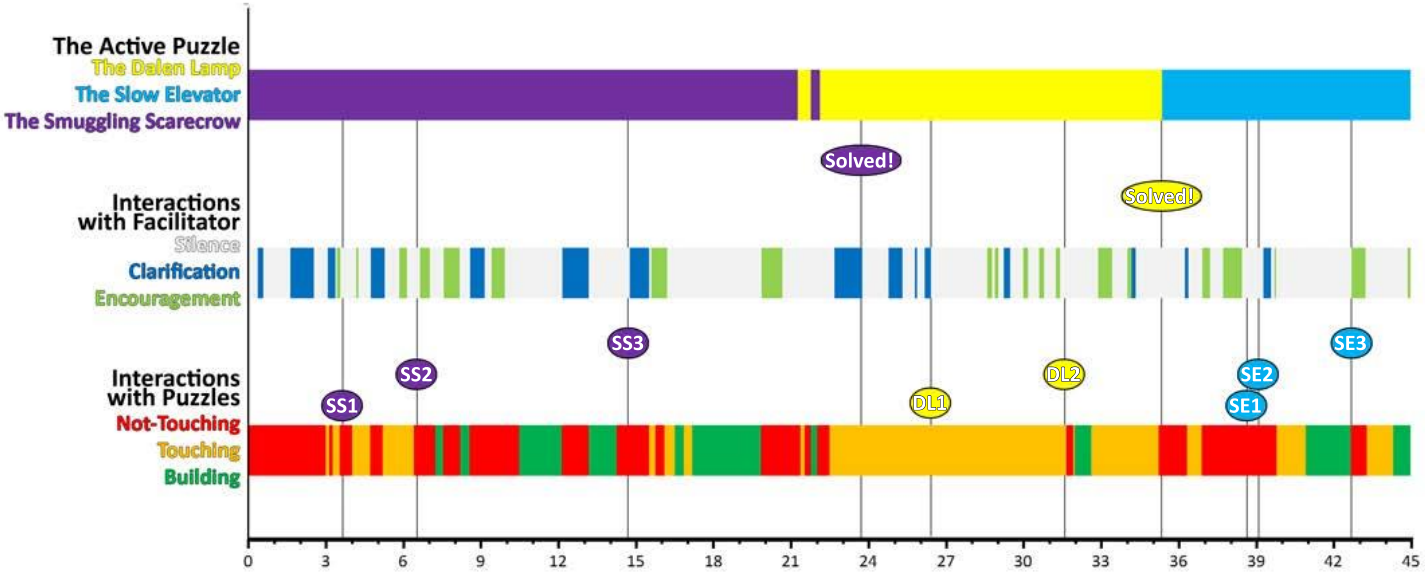


Participant 19: Female; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **8th** (shared)
Extrinsic Motivation: **14th**
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **3rd**
The Slow Elevator: **15th**
The Smuggling Scarecrow: **6th**
Overall Placement: **8th**

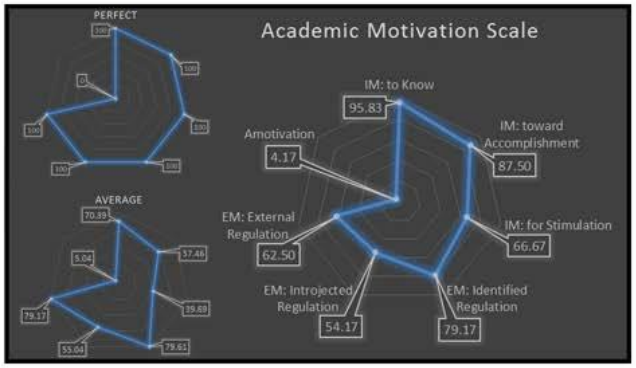


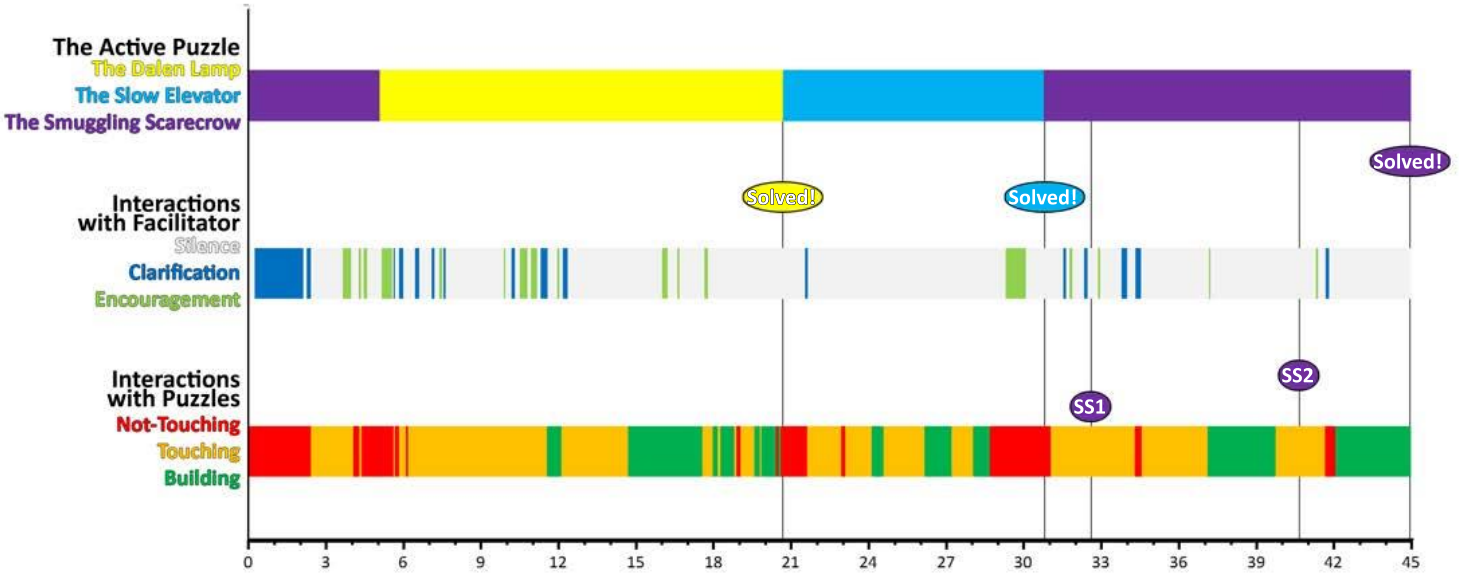


Participant 20: Female; 2nd Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **2nd**
Extrinsic Motivation: **22nd**
Amotivation: **12th** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **4th**
The Slow Elevator: **4th**
The Smuggling Scarecrow: **5th**
Overall Placement: **1st**

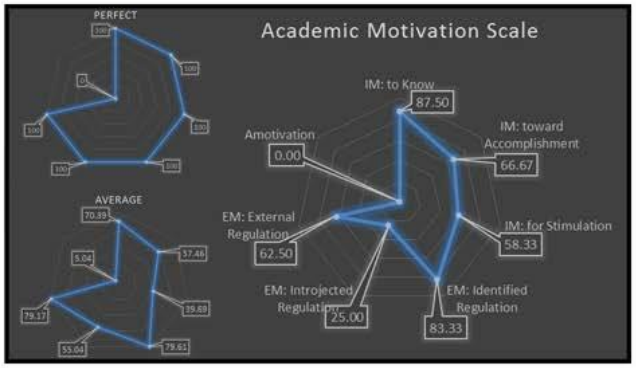


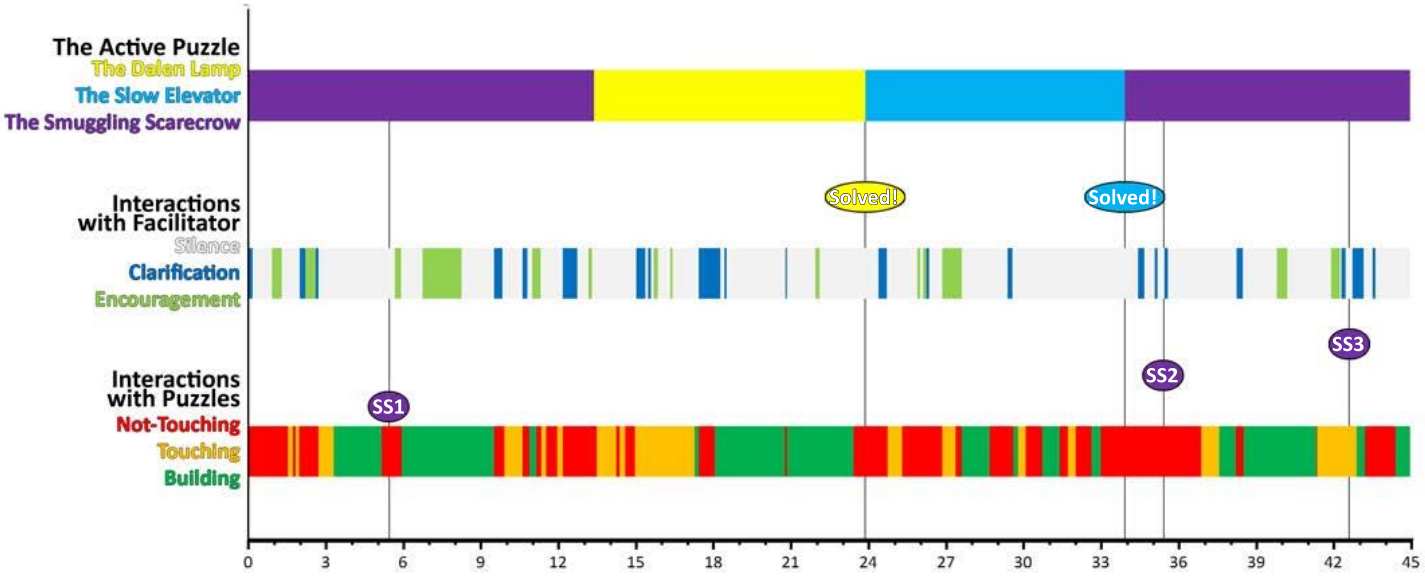


Participant 21: Male; 3rd Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **11th**
Extrinsic Motivation: **28th** (shared)
Amotivation: **31st** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **1st**
The Slow Elevator: **2nd**
The Smuggling Scarecrow: **10th**
Overall Placement: **3rd**

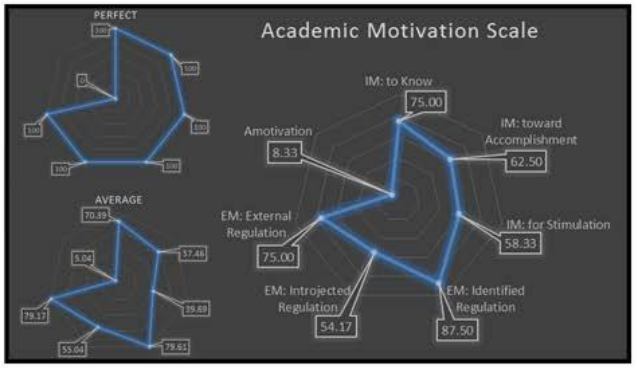


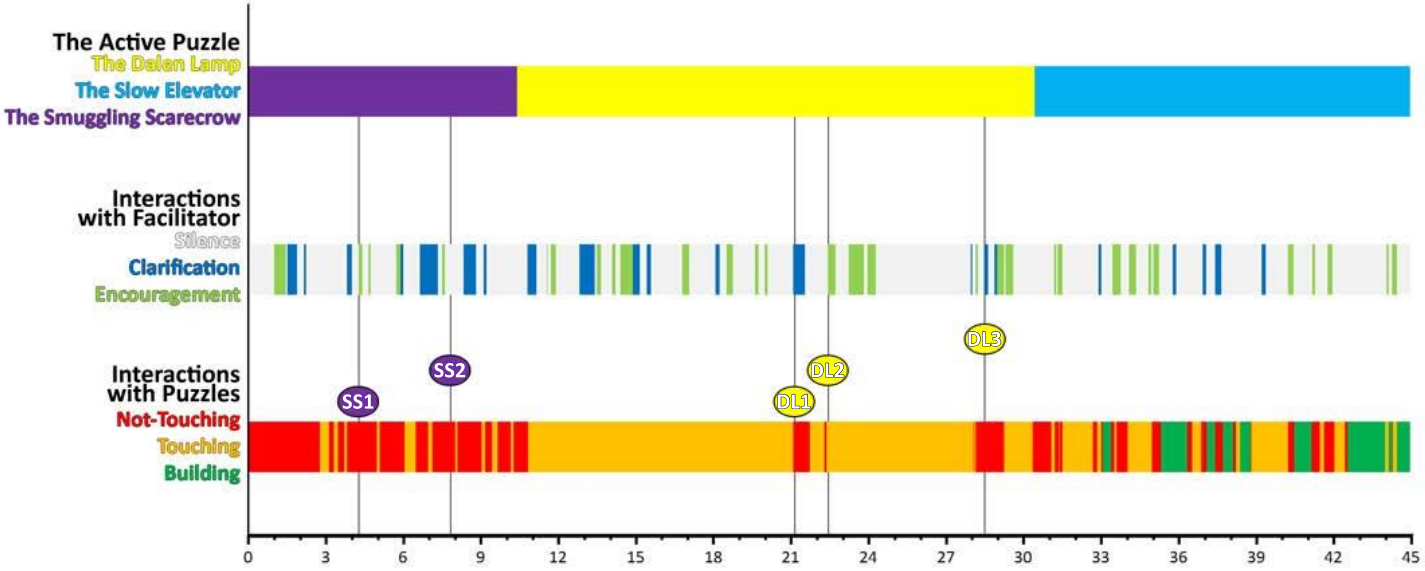


Participant 22: Female; 4th Year

Academic Motivation Scale (from 1st to 31st)
Intrinisic Motivation: **12th** (shared)
Extrinsic Motivation: **18th**
Amotivation: **8th** (shared)

Puzzle Performances (from 1st to 19th)
The Dalen Lamp: **14th**
The Slow Elevator: **13th**
The Smuggling Scarecrow: **19th**
Overall Placement: **18th**

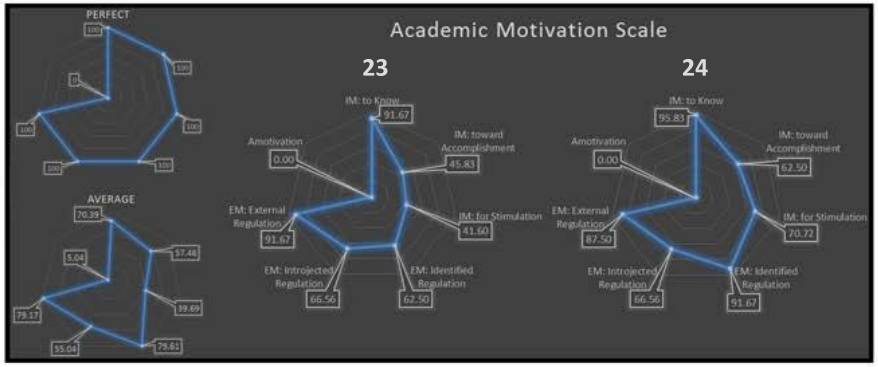




Participant 23: Female; Masters
Participant 24: Male; Masters

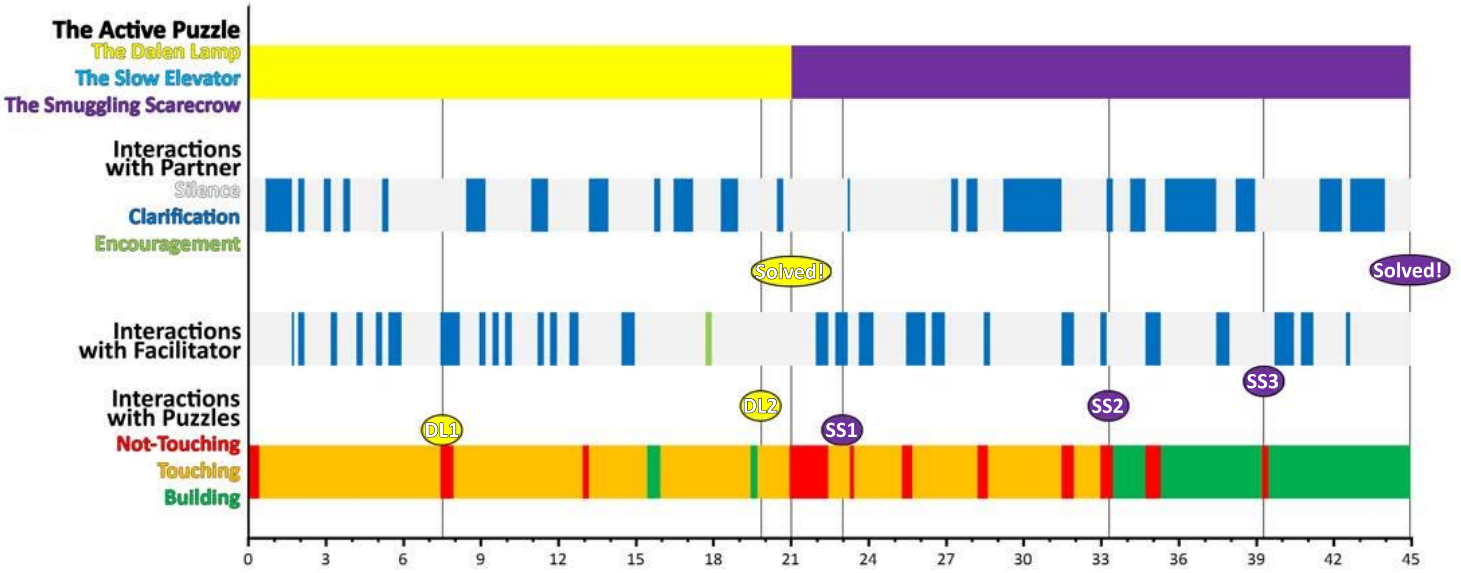
Academic Motivation Scale (from 1st to 31st)

	P23	P24
Intrinisic Motivation:	**17th**	**4th** (scared)
Extrinsic Motivation:	**16th** (shared)	**9th**
Amotivation:	**31st** (shared)	**31st** (shared)



Puzzle Performances (from 1st to 6th)

The Dalen Lamp:	**2nd**
The Slow Elevator:	**6th**
The Smuggling Scarecrow:	**4th**
Overall Placement:	**4th**



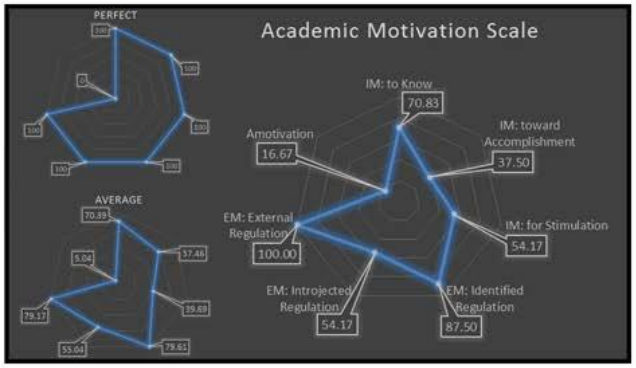
Participant 25: Male; 3rd Year

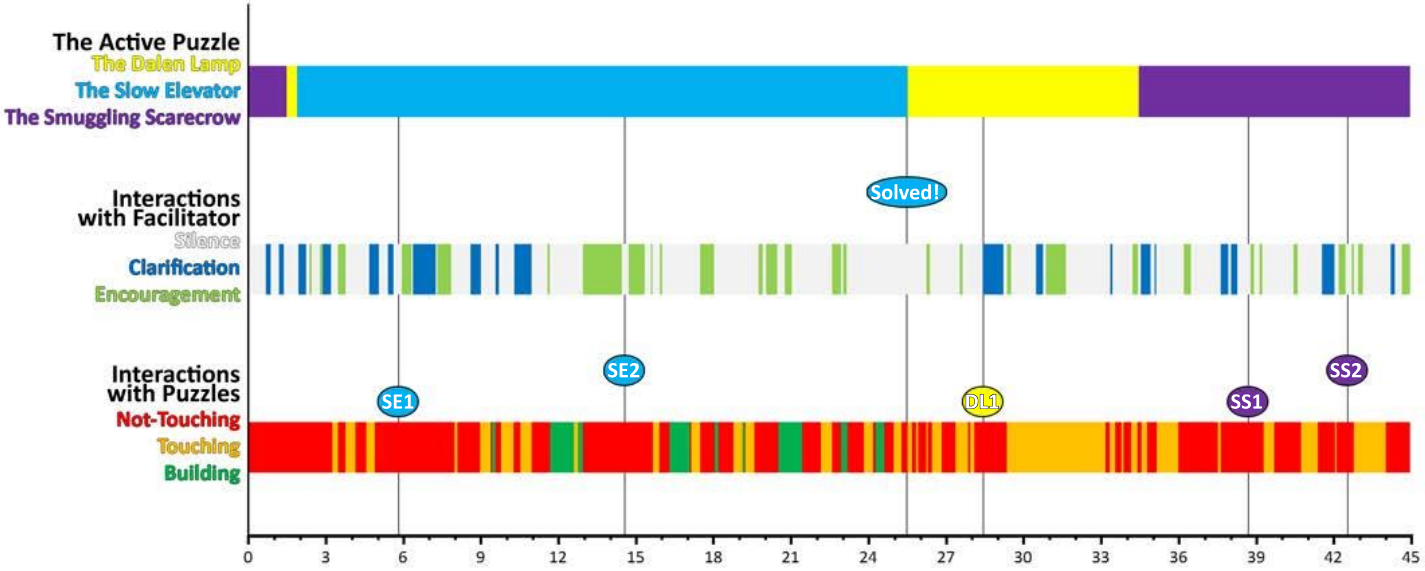
Academic Motivation Scale (from 1st to 31st)

Intrinisic Motivation:	**20th**
Extrinsic Motivation:	**10th**
Amotivation:	**6th** (shared)

Puzzle Performances (from 1st to 19th)

The Dalen Lamp:	**11th**
The Slow Elevator:	**11th**
The Smuggling Scarecrow:	**17th**
Overall Placement:	**13th**

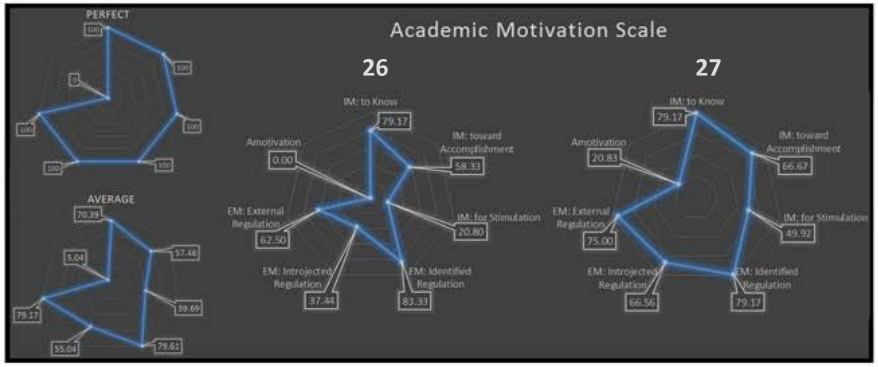




Participant 26: Female; 2nd Year
Participant 27: Male; 2nd Year

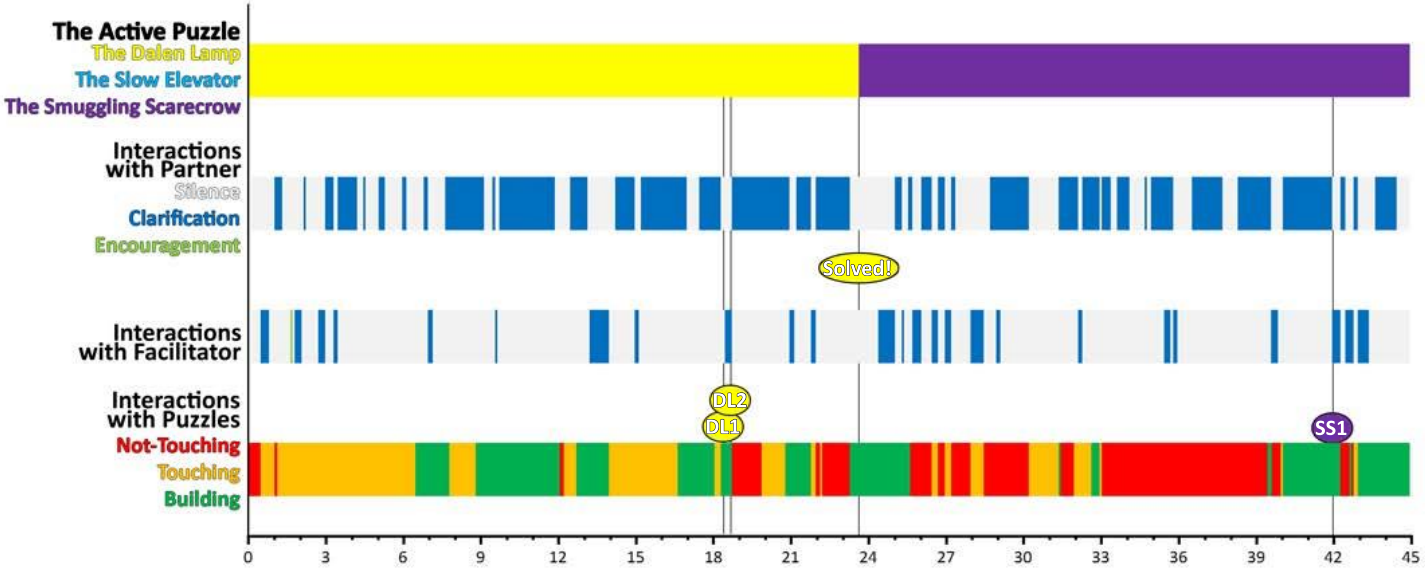
Academic Motivation Scale (from 1st to 31st)

	P26	P27
Intrinisic Motivation:	**23rd** (shared)	**12th** (shared)
Extrinsic Motivation:	**23rd** (shared)	**16th** (shared)
Amotivation:	**31st** (shared)	**4th** (shared)



Puzzle Performances (from 1st to 6th)

The Dalen Lamp:	**3rd**
The Slow Elevator:	**6th**
The Smuggling Scarecrow:	**6th**
Overall Placement:	**6th**



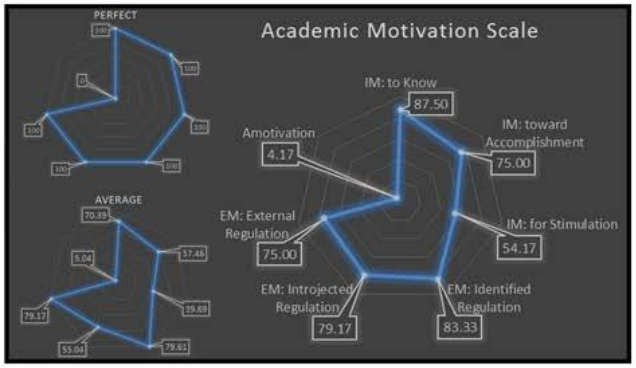
Participant 28: Female; 4th Year

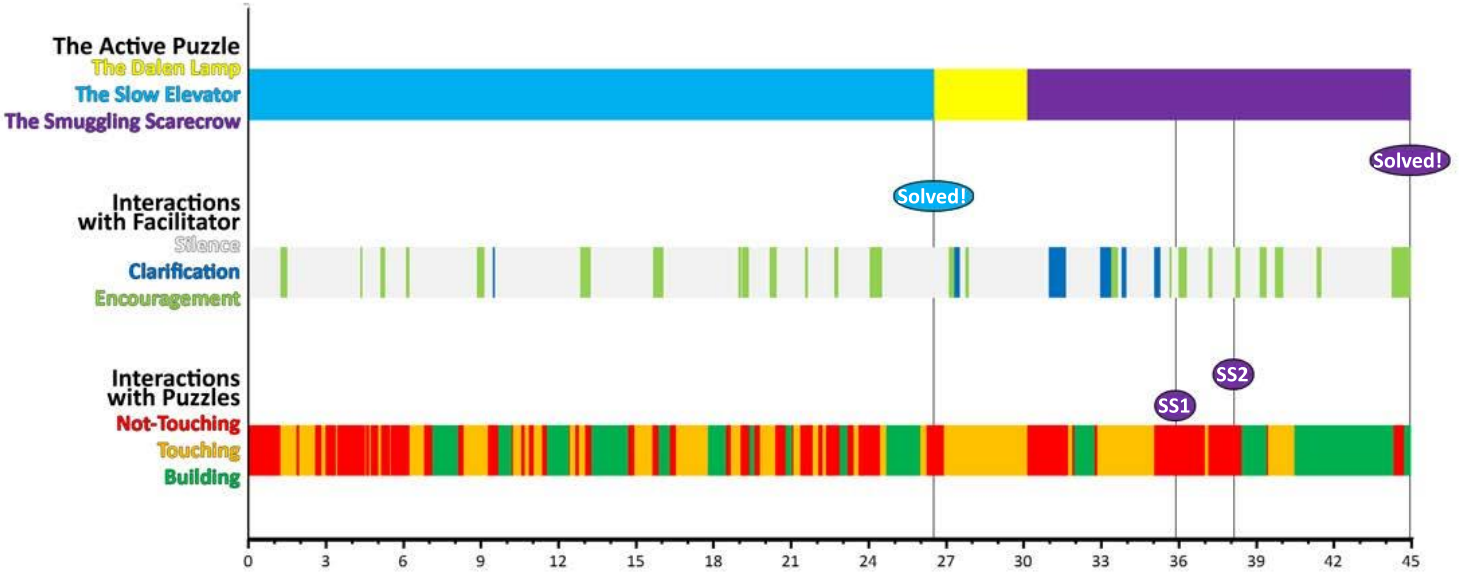
Academic Motivation Scale (from 1st to 31st)

Intrinisic Motivation:	**8th** (shared)
Extrinsic Motivation:	**11th** (shared)
Amotivation:	**12th** (shared)

Puzzle Performances (from 1st to 19th)

The Dalen Lamp:	**17th**
The Slow Elevator:	**12th**
The Smuggling Scarecrow:	**4th**
Overall Placement:	**9th**

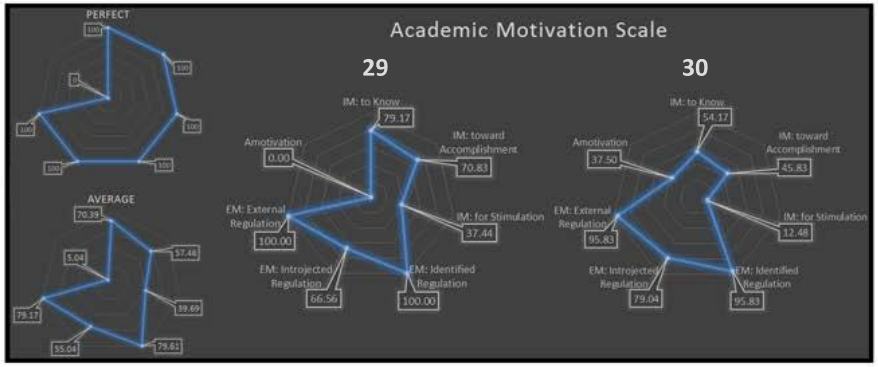




Participant 29: Female; 3rd Year
Participant 30: Female; 3rd Year

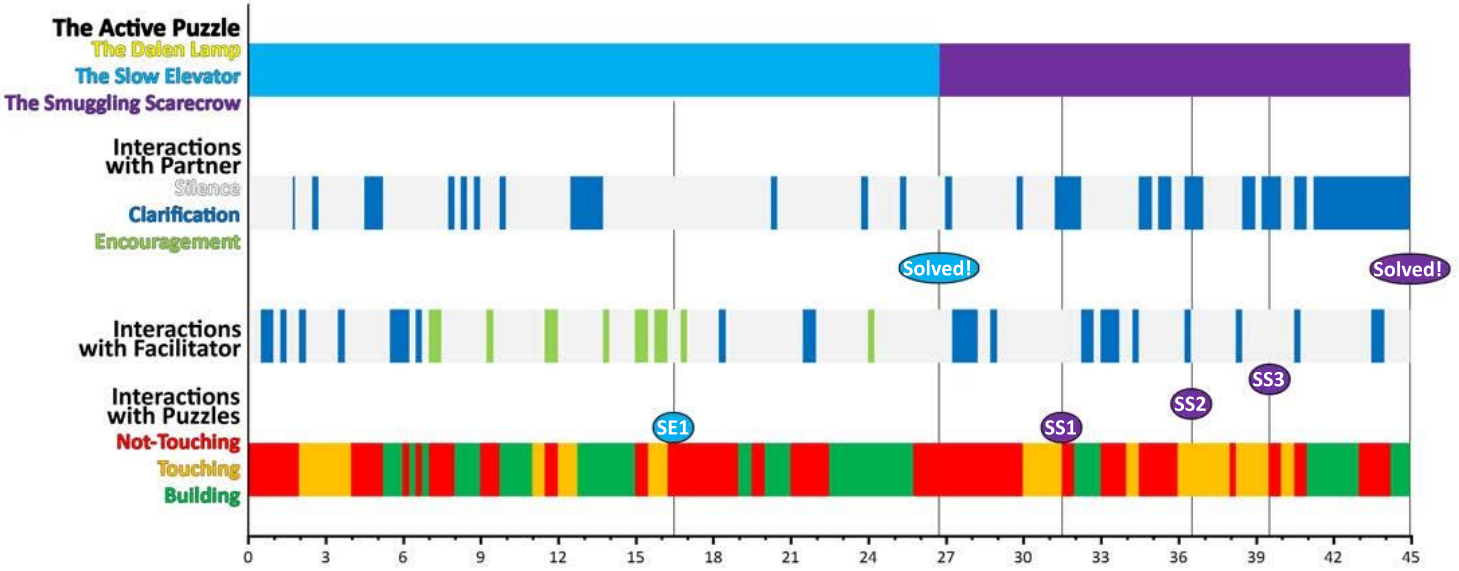
Academic Motivation Scale (from 1st to 31st)

	P29	P30
Intrinisic Motivation:	**16th**	**27th**
Extrinsic Motivation:	**3rd** (shared)	**1st** (shared)
Amotivation:	**31st** (shared)	**2nd**



Puzzle Performances (from 1st to 6th)

The Dalen Lamp:	**6th**
The Slow Elevator:	**2nd**
The Smuggling Scarecrow:	**3rd**
Overall Placement:	**3rd**



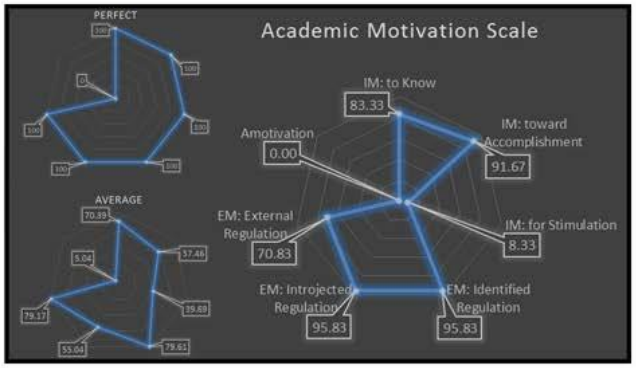
Participant 31: Female; 3rd Year

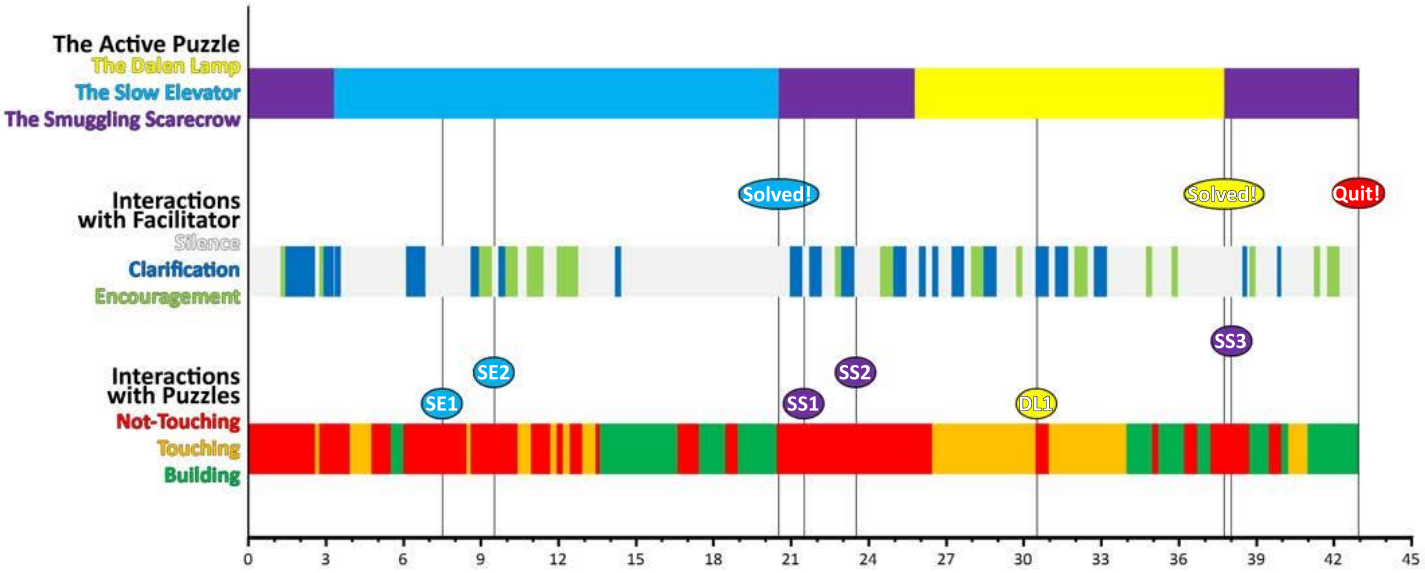
Academic Motivation Scale (from 1st to 31st)

Intrinisic Motivation:	**16th**
Extrinsic Motivation:	**5th**
Amotivation:	**31st** (shared)

Puzzle Performances (from 1st to 19th)

The Dalen Lamp:	**2nd**
The Slow Elevator:	**8th**
The Smuggling Scarecrow:	**12th**
Overall Placement:	**5th** (shared)





Appendix B

B1 ANOVA - An Analysis of Variance

As the intent of this numerical analysis of their activities was to quantify any patterns in behaviour and to then extract meaning, ANOVA was chosen as the test instrument.

A 'One Way ANOVA' is an analysis of variance. The result of this calculation is expressed in the test statistic 'F'. This ratio expresses how much variability there is between the groups relative to how much there is within the groups, characterized by two numbers:

1. The numerator degrees of freedom (df1): One less than the number of groups.
2. The denominator degrees of freedom (df2): The total number of observations minus the number of groups.

The p-value can be calculated from the values of F, df1, and df2[37]. If the p-value is significant (e.g. less than 0.05), then you can conclude that the groups are not all the same, as the means varied from each other by too large an amount to be expected if they were all the same.

ANOVA testing can reveal an overall difference between your groups, but it does not tell you which specific groups differed. A post-hoc test will do this, but they should only be run when you have shown an overall statistically significant difference in 'group means' (i.e., a statistically significant one-way ANOVA result). This post-hoc testing deals with 'experiment-wise error rate', the committing of a Type 1 error: the rejection of a true null hypothesis (a false positive).

The results are presented with puzzle-specific compilations of the participants' activities. Both the ANOVA results and the timelines are presented in full in the Appendices. Although reading through them is interesting, directly comparing all the timelines is not useful, as participants varied in their choices regarding puzzle order, and almost identical behaviours with each puzzle would appear unrelated because of this displacement.

[37] Microsoft's EXCEL was used to perform these calculations.

B 1.1 Not-Touching, Touching, and Building (NtTB)

B2 The Dalén Lamp puzzle

7 individuals & 3 pairs started with this puzzle. In interview, many revealed that this was because it was the smallest puzzle and seemed the least intimidating. Ironically, it would prove to be the most difficult to solve, with only 6 individuals and 3 pairs completing it, an overall success rate of 36%. As 29/31 attempted this puzzle, it has a marginally higher 'if attempted' success rate of 39.1%. This is compared with the 'if attempted' success rates of 48% for The Smuggling Scarecrow, and 66.7% for The Slow Elevator.

B2.1 The Dalén Lamp: Not-Touching/Touching/Building (NtTB)

The fastest solve was by P21, in 628 seconds (10 minutes, 28 seconds), and the slowest solve was by the pairing of P26 & P27, who solved it in 1420 seconds (23 minutes, 40 seconds). Remember: Red for Not-Touching; Amber for Touching; Green for Building, see Figure 120 below.

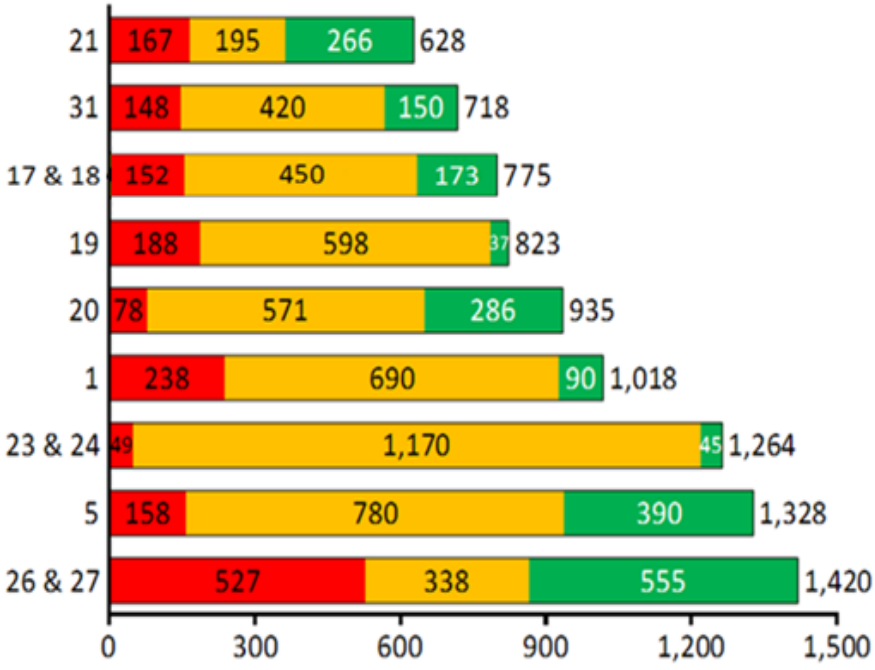


Figure 120 The Dalén Lamp NtTB Solve Results

Figure 121, see below, is a breakdown of the same participants, but as puzzle-specific extracts from their individual timelines, with all physical activities in the precise order of when they did what.

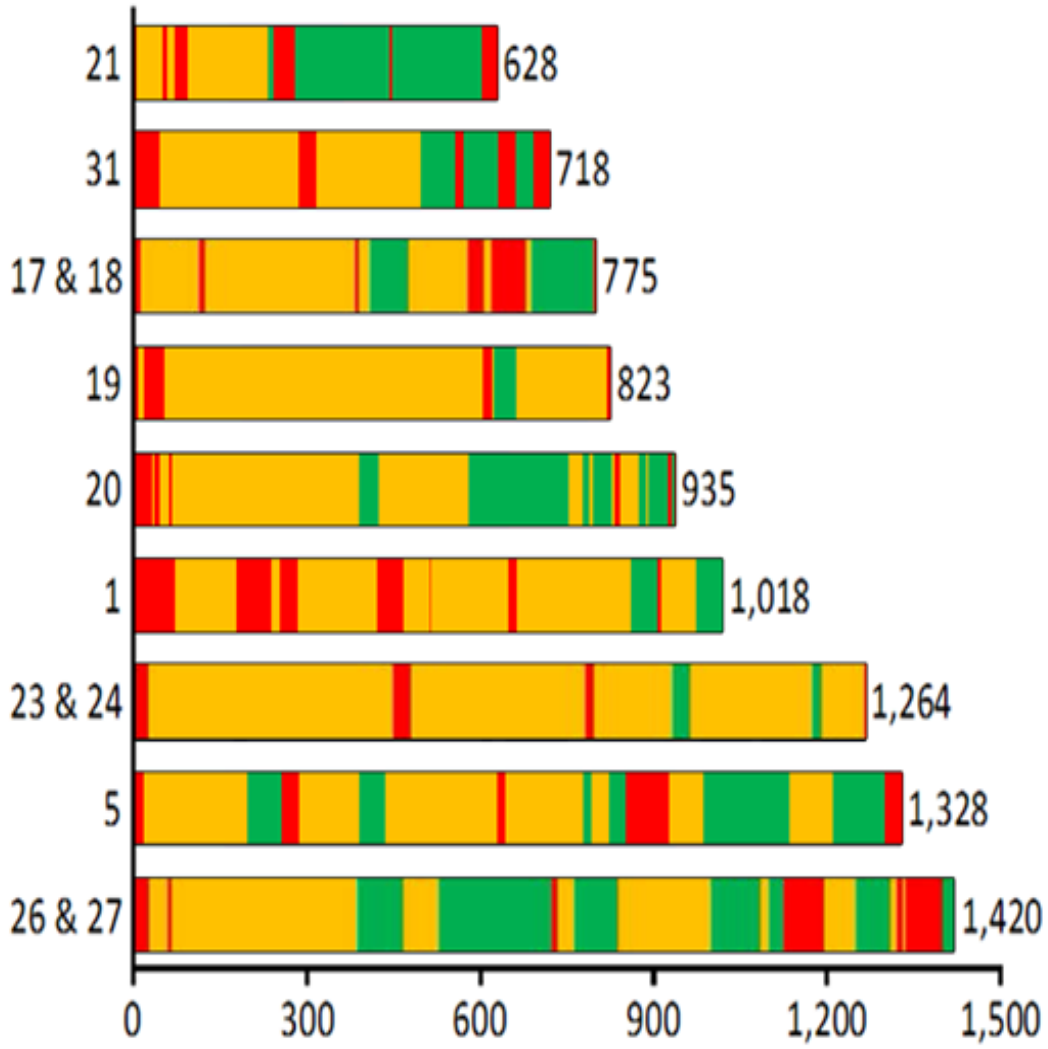


Figure 121 The Dalén Lamp NtTB Breakdown

Figure 122 below, presents the same information, but with all activities presented in percentages. Fastest solve is on the left, (P21), second fastest (P31) is next, etc.

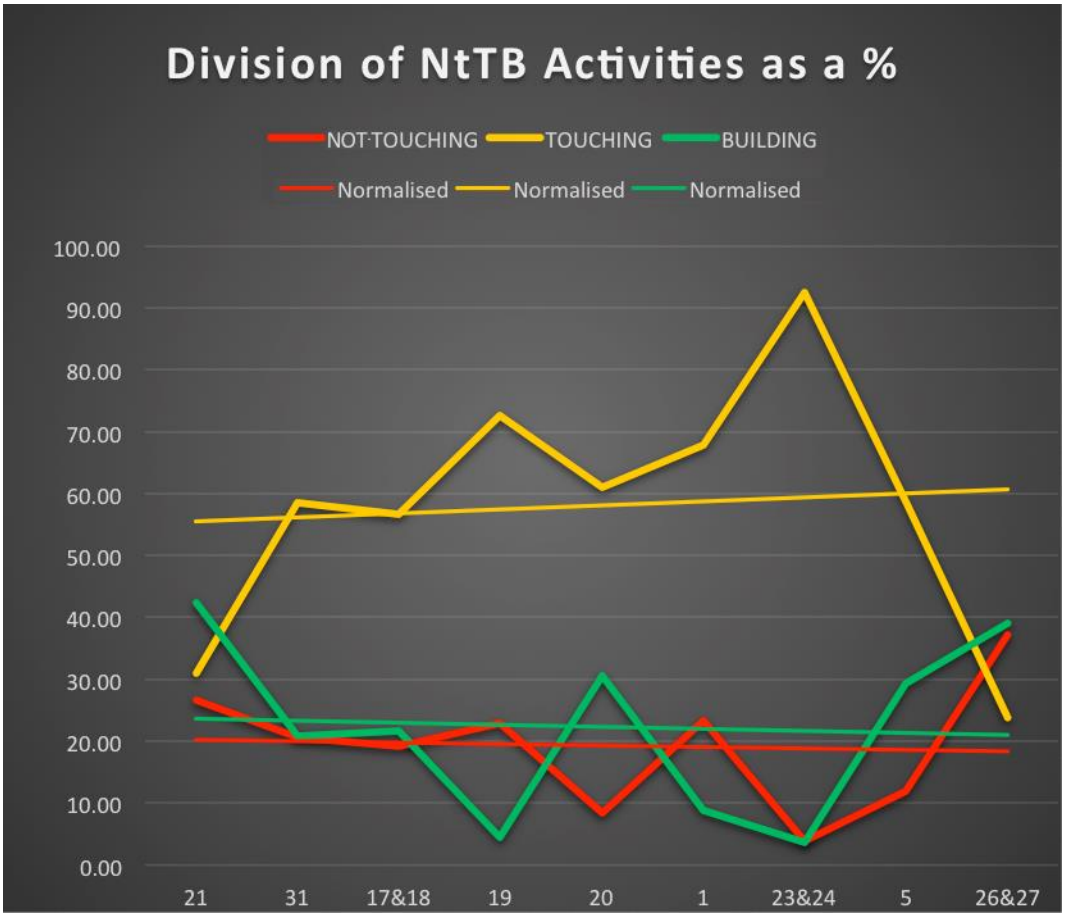


Figure 122 The Dalén Lamp: NtTB Activities (%)

P21 spent 26.6% of his time 'Not-Touching' the puzzle, 31% 'touching' it in an exploratory way and 42.4% actively 'building' a possible solution (in a total of 10 minutes, 28 seconds). P19 spent 22.8% of her time 'Not-Touching' about the puzzle, 72.7% 'touching' it in an exploratory way and only 4.5% actively 'building' a possible solution (in a total of 13 minutes, 43 seconds). P21 split his time reasonably evenly between activities, whereas P19 built a solution in a spectacular 37 seconds, after spending nearly 10 minutes in total touching the puzzle in a probing, exploratory way. P23 & P24 spent 92.6% of their time touching the puzzle, successfully building a solution with less than 4% of their total time, (45 seconds).

Hypotheses:

1. $H_{0:}$ There are no statistically significant variances between ‘Not-Touching’, ‘Touching’ and ‘Building’.
2. $H_{A:}$ There are statistically significant variances between ‘Not-Touching’, ‘Touching’ and ‘Building.

‘Not-Touching’, ‘Touching’ and ‘Building’ are separate activities and are independent of each other. A participant could have never touched, or always been touching a puzzle, but only one activity at a time.

The ANOVA results of those that solved The Dalén Lamp puzzle were as follows:

1. There was a statistically significant difference between the groups as determined by one-way ANOVA ($F(2,24) = 11.139$, $p = .000378$).

In general, if the calculated F value (11.139) is larger than the F crit (3.4), you can reject the null hypothesis, with the p-value reinforcing this. So the null hypothesis that “there are no statistically significant variances between ‘Not-Touching’, ‘Touching’ and ‘Building’ between the students who solved The Dalén Lamp puzzle is rejected.

A post-hoc test revealed a statistically significant difference between the:

1. ‘Not-Touching’ and ‘Touching’ grouping ($F(1,16) = 15.966$, $p = .001041$)
2. ‘Touching’ and ‘Building’ grouping ($F(1,16) = 11.795$, $p = .0003404$)

However, there was no statistically significant difference between the ‘Not-Touching’ and ‘Building’ grouping ($F(1,16) = 0.399$, $p = 0.53643$).

B2.2 The Dalén Lamp: Clarification/Encouragement/Silence (CES)

Colour-coding: Blue for Clarification; Green for Encouragement; Grey for Silence.

Here, P21 spent 86 seconds asking for and getting 'clarification', 24 seconds getting 'encouragement', with 518 seconds of 'silence' (78% of the time spent on the puzzle).

For everyone, the blue and green on the left represents clarification/encouragement from me, grey is silence and, for the pairs, any blue/green on the right represents clarification/encouragement from each other, see Figure 123, below. The 3 pairs required minimal encouragement from the Facilitator and gave none at all to each other. Any interaction between them was explicit clarification, i.e. asking/answering their partner's question.

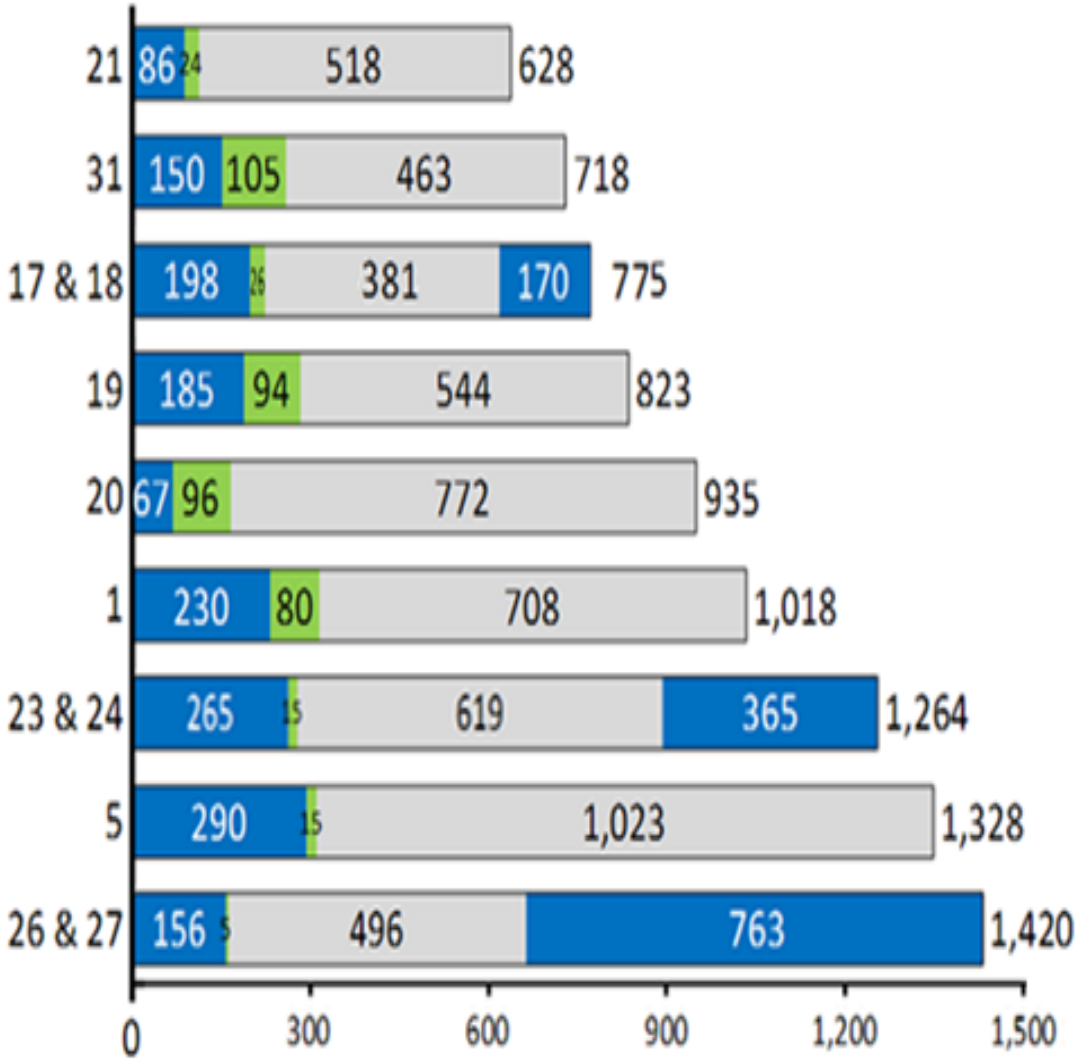


Figure 123 The Dalén Lamp CES Solve Results

Figure 124, see below, is a breakdown of the same participants, but with puzzle-specific extracts from their individual timelines, with all ‘relatedness’. For the pairs of participants, the top half of the bar is any interaction between the participants, and the lower half is any interaction between them and the Facilitator.

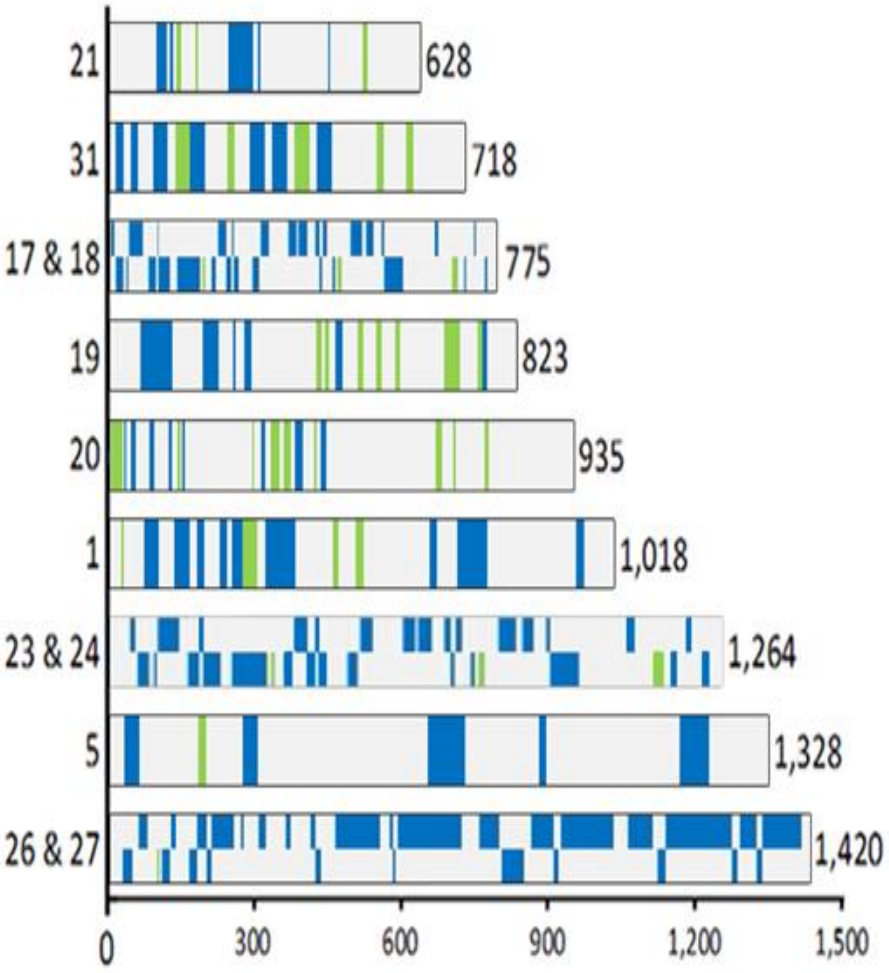


Figure 124 The Dalén Lamp CES Breakdown

Figure 125 below, presents the same information, but with all activities presented in percentages. Fastest solve is on the left, (P21), second fastest (P31) is next, etc.

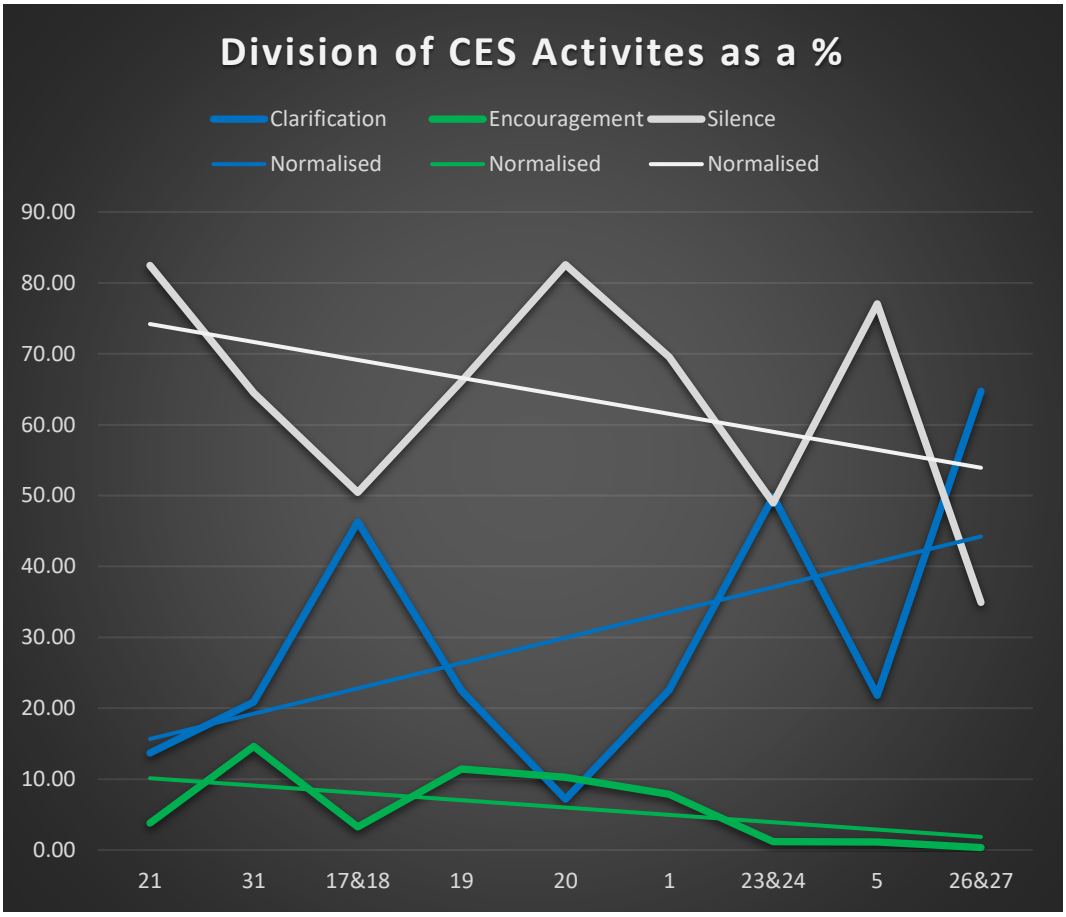


Figure 125 The Dalén Lamp: CES Activities (%)

P21 (1st) & P20 (5th) both spent 82% of their time in silence, generally ignoring the Facilitator's presence, while there was an expected increase in the percentage of time spent with 'clarification' when that included dealing with a partner.

Hypotheses:

1. $H_{0:}$ There are no statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.
2. $H_{A:}$ There are statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.

‘Clarification’, ‘Encouragement’ and ‘Silence’ are separate activities and were independent of each other. A participant could have never engaged with the Facilitator and/or their partner or done so continuously.

The ANOVA results of those that solved The Dalén Lamp puzzle were as follows:

1. There was a statistically significant difference between groups as determined by one-way ANOVA ($F(2,24) = 18.328$, $p = 1.47^{-5}$).

In general, if the calculated F value (18.328) is larger than the F crit (3.4), you can reject the null hypothesis, with the p-value reinforcing this. So, the null hypothesis that “there are no variances between ‘Clarification’, ‘Encouragement’ and ‘Silence’” between the students who solved The Dalén Lamp puzzle is rejected.

A post-hoc test revealed that there remained a statistically significant difference between the:

1. ‘Clarification’ and ‘Encouragement’ grouping ($F(1,16) = 8.366$, $p = .010605$).
2. ‘Encouragement’ and ‘Silence’ grouping ($F(1,16) = 74.274$, $p = 2.08^{-7}$).
3. ‘Clarification’ and ‘Silence’ grouping ($F(1,16) = 6.586$, $p = 0.0207$).

B3 The Slow Elevator

Out of the 25 explorations, only 3 (2 individuals & 1 pair) started with this puzzle. It would prove to be the easiest to solve, with 12 individuals and 2 pairs completing it, an overall success rate of 56%. Every individual attempted it but only 3 of the 6 pairs did, so we have an increased 66.7% success rate 'if attempted'.

B3.1 The Slow Elevator: Not-Touching/Touching/Building (NtTB)

The fastest solve was by P2, in 432 seconds (7 minutes, 12 seconds), and the slowest solve was by the pairing of P29 & P30, who solved it in 1606 seconds (26 minutes, 46 seconds). 1620 seconds (the x-axis) is 27 minutes, see Figure 126 below.

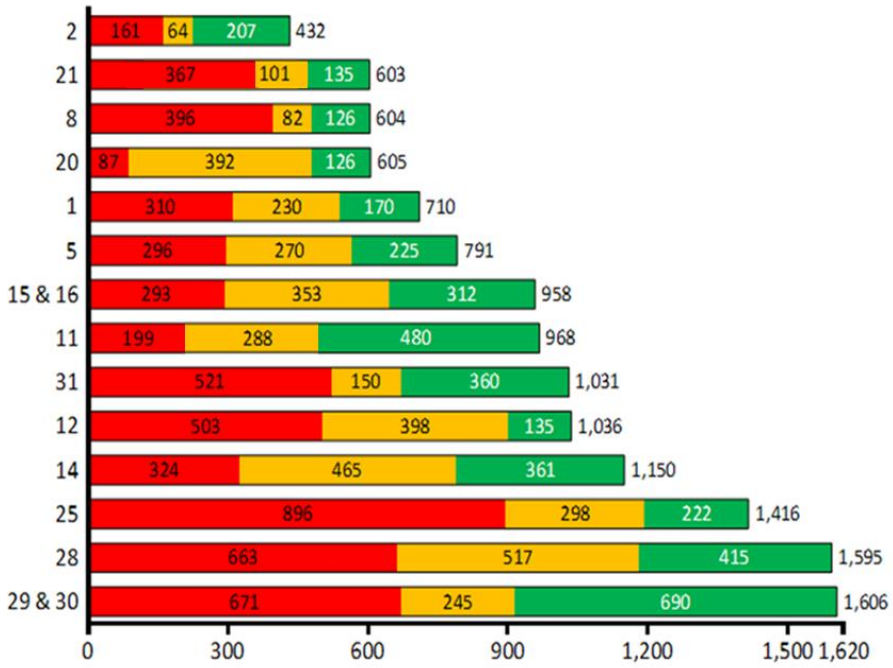


Figure 126 The Slow Elevator NtTB Solve Results

Figure 127 is a puzzle-specific extract from their individual timelines, with all physical activities in the precise order of when they did what.

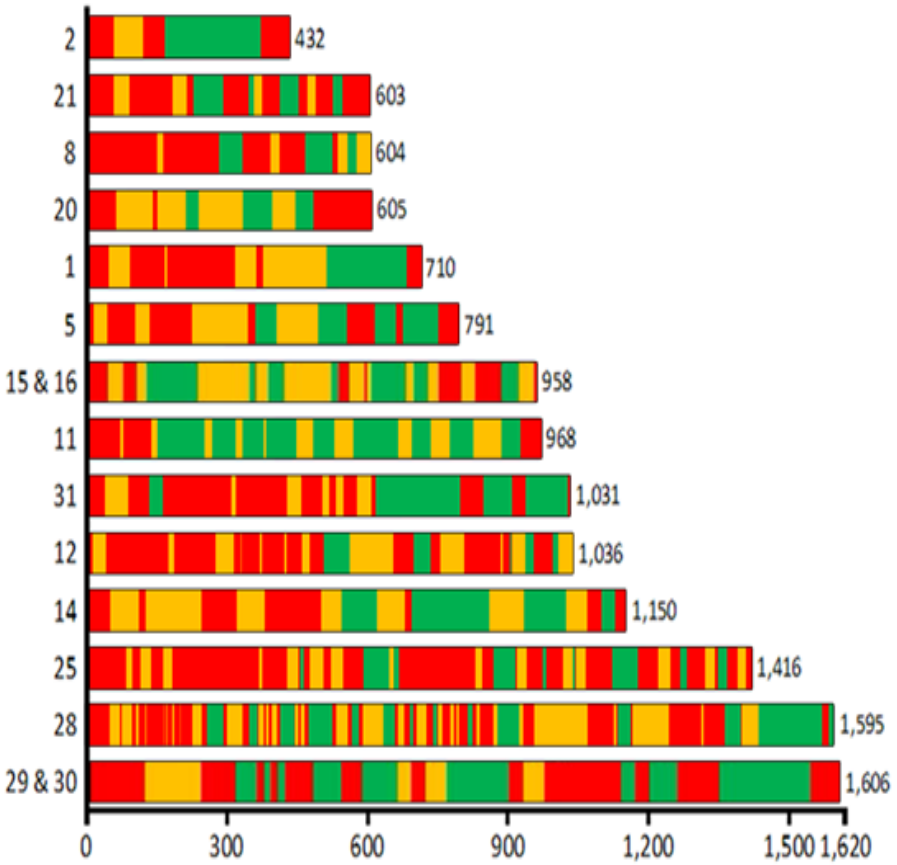


Figure 127 The Slow Elevator NtTB Solve Breakdown

Figure 128 below, presents the same information, but with all activities presented in percentages. Fastest solve is on the left, (P2), second fastest (P21) is next, etc.

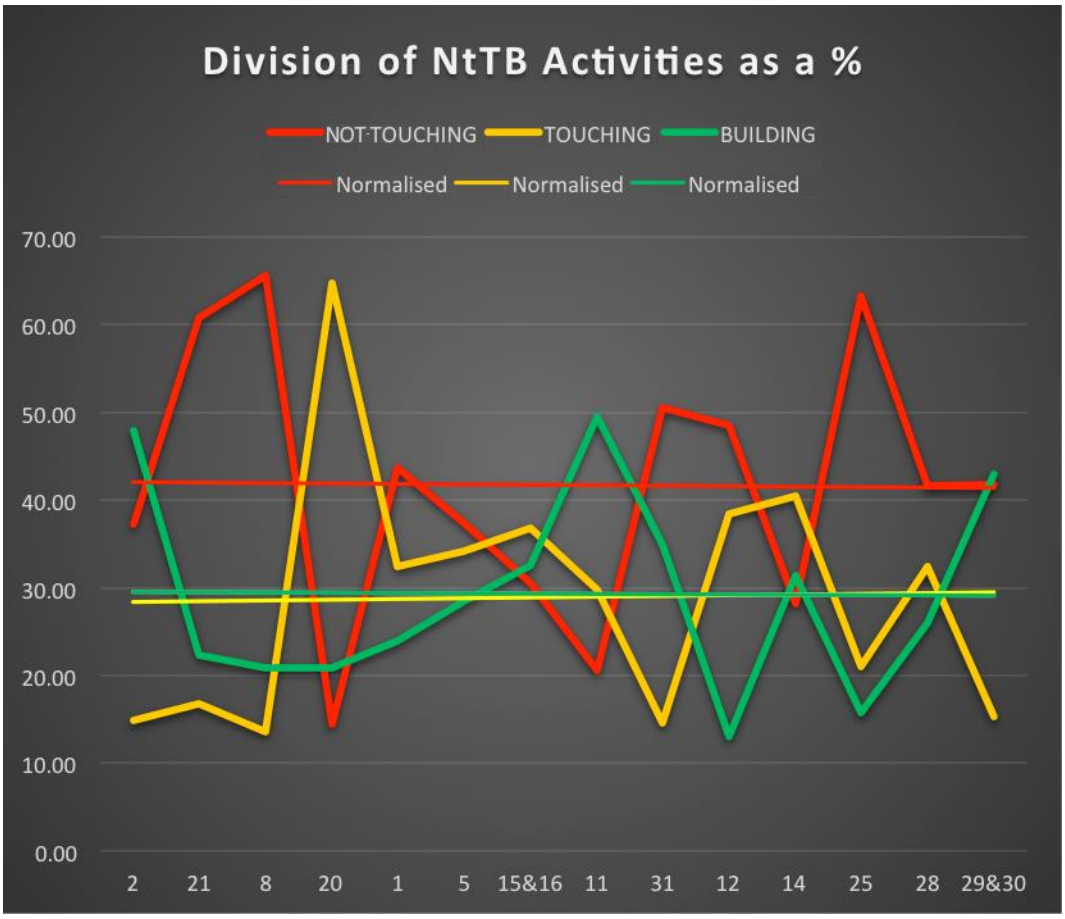


Figure 128 The Slow Elevator: NtTB Activities (%)

The shortest build time for this puzzle was 126 seconds, by P20 & P8.

Their remaining times were almost perfect inverses of each other (P8 spent 396 seconds 'Not-Touching', and 82 seconds 'Touching'; P20 spent 87 seconds 'Not-Touching', and 392 seconds 'Touching').

Hypotheses:

1. $H_{0:}$ There are no statistically significant variances between 'Not-Touching', 'Touching' and 'Building'.
2. $H_{A:}$ There are statistically significant variances between 'Not-Touching', 'Touching' and 'Building'.

‘Not-Touching’, ‘Touching’ and ‘Building’ are separate activities and are independent of each other. A participant could have never touched, or always been touching a puzzle, but only one activity at a time.

The ANOVA results of those that solved The Slow Elevator puzzle are as follows:

1. There was a statistically significant difference between the groups as determined by one-way ANOVA ($F(2,39) = 2.337$, $p = .1099$).

Here, as the calculated F value (2.34) is smaller than the F crit (3.24), the null hypothesis of “there are no statistical variances between ‘Not-Touching’, ‘Touching’ and ‘Building’” between the students who solved The Slow Elevator puzzle cannot be rejected. The p-value (0.11) reinforces this.

Because of this result, there was no need for any post-hoc testing.

B3.2 The Slow Elevator: Clarification/Encouragement/Silence (CES)

Here, P2 spent 50 seconds asking for and getting ‘clarification’, 17 seconds getting ‘encouragement’, with 365 seconds of ‘silence’, (81.6% of the time spent on the puzzle). Only 1 of the pairs required any encouragement from the Facilitator (for 29 seconds), and neither pairing gave any to each other, see Figure 129 below.

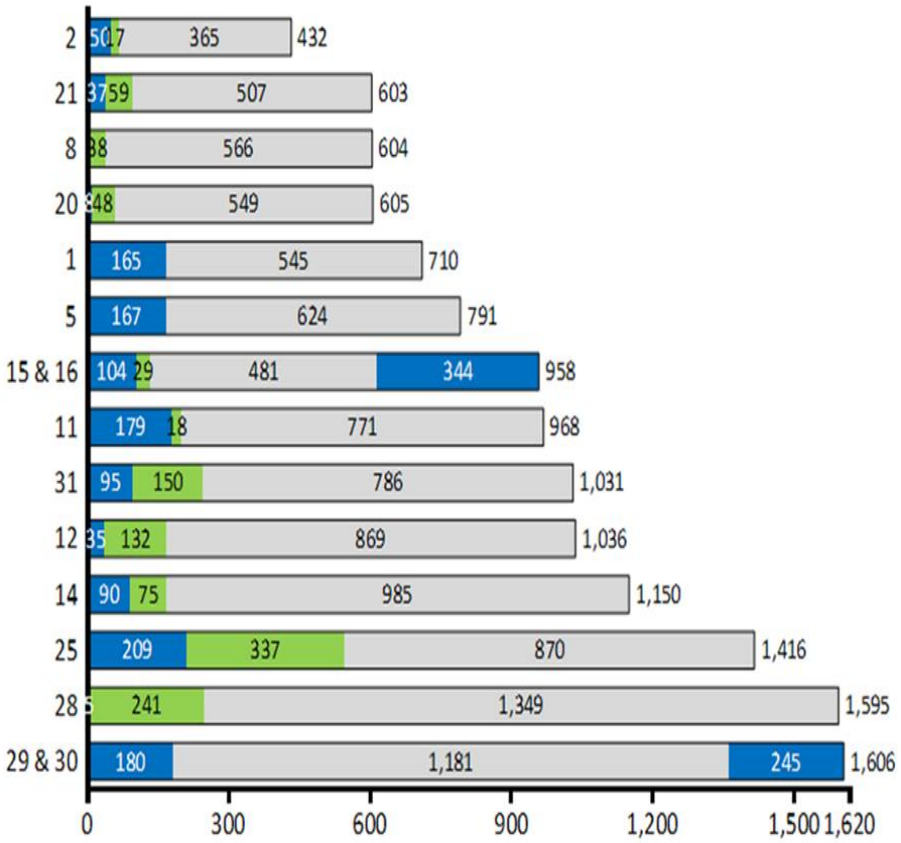


Figure 129 The Slow Elevator CES Solve Results

Figure 130, see below, is a breakdown of the same participants, with all human interactions in precise order of when they did what.

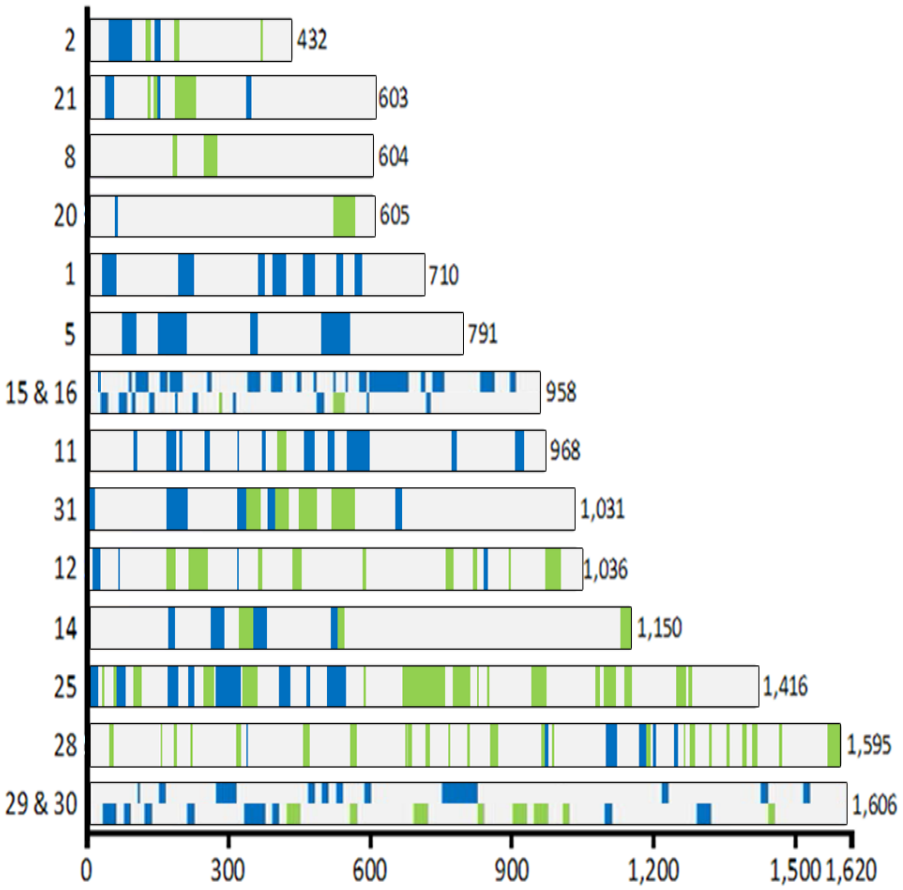


Figure 130 The Slow Elevator CES Breakdown

Figure 131 below, presents all human interaction activities, presented in percentages.

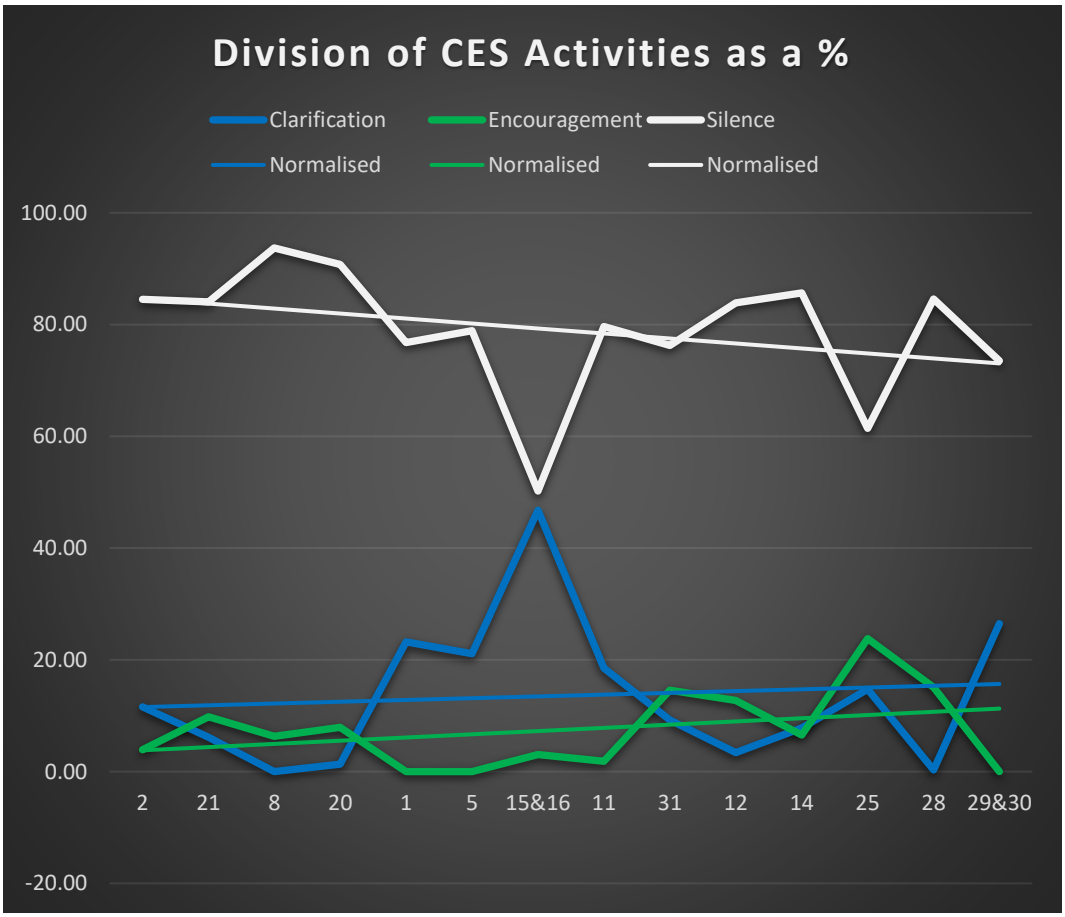


Figure 131 The Slow Elevator: CES Activities (%)

Hypotheses:

1. $H_{0:}$ There are no statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.
2. $H_{A:}$ There are statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.

'Clarification', 'Encouragement' and 'Silence' are separate activities and were independent of each other. A participant could have never engaged with the Facilitator and/or their partner or done so continuously.

The ANOVA results of those that solved The Slow Elevator puzzle were as follows:

1. The calculated F value (51.33) is larger than the F crit (3.238), so I can reject the null hypothesis. The p-value (an extreme 1.9^{-11}) reinforces this.

In general, if the calculated F value (51.33) is larger than the F crit (3.238), you can reject the null hypothesis, with the p-value reinforcing this. So, the null hypothesis that "there are no statistical variances between 'Clarification', 'Encouragement' and 'Silence' between the students who solved the Slow Elevator puzzle can be rejected.

A post-hoc test revealed that there remained a statistically significant difference between the:

1. 'Encouragement' and 'Silence' grouping ($F(1,26) = 68.462$, $p = 9.35^{-9}$).
2. 'Clarification' and 'Silence' grouping ($F(1,26) = 51.448$, $p = 1.29^{-7}$).

However, there was no statistically significant difference between the 'Clarification' and 'Engagement' grouping ($F(1,26) = 1.354$, $p = 0.255$).

B4 The Smuggling Scarecrow

Out of the 25 explorations, 12 (10 individuals & 2 pairs) started with this puzzle. 7 individuals and 5 pairs completed it, a success rate of 48% (everyone attempted this puzzle), compared with 39.1% for The Dalén Lamp and 66.7% for The Slow Lift.

B4.1 The Smuggling Scarecrow: Not-Touching/Touching/Building (NtTB)

P11 solved the puzzle in 241 seconds (4 minutes, 1 second), and the pairing of P9 & P10 solved the puzzle in 1552 seconds (25 minutes, 52 seconds). 1620 seconds equates to 27 minutes, see Figure 132 below.

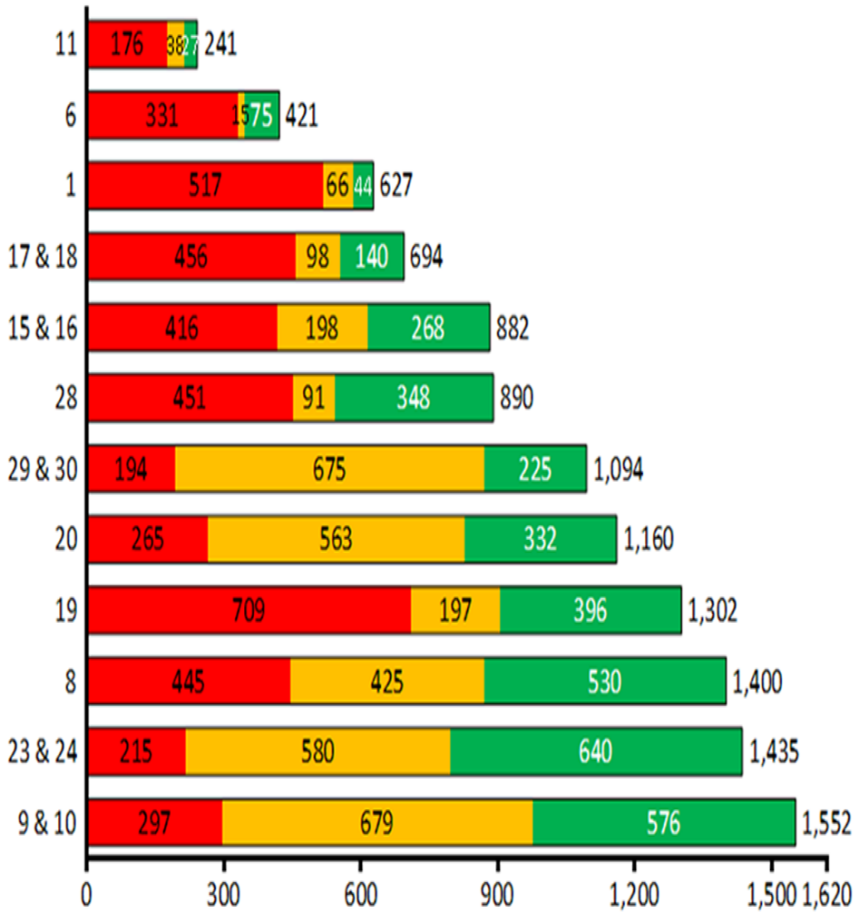


Figure 132 The Smuggling Scarecrow NtTB Solve Results

Figure 133 is a puzzle-specific extract from their individual timelines.

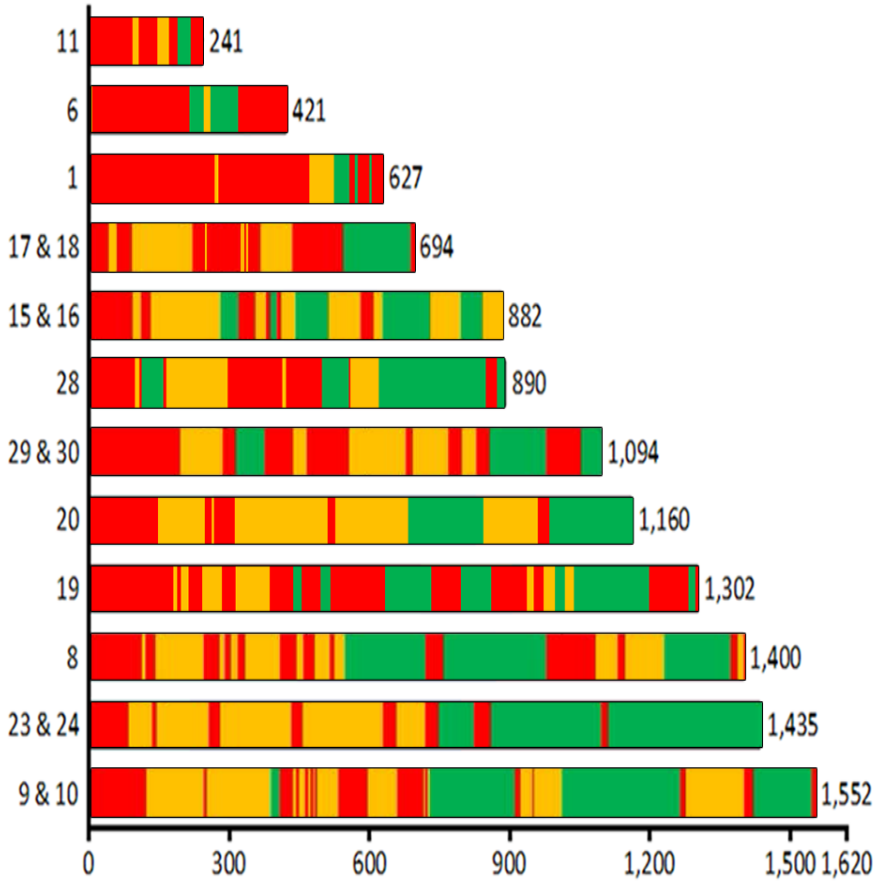


Figure 133 The Smuggling Scarecrow NtTB Breakdown

Figure 134 below, presents the same information, but with all activities presented in percentages. Fastest solve is on the left, (P11), second fastest (P6) is next, etc. P11 spent 73% of his time 'Not-Touching' about the puzzle, 15.8% 'touching' it in an exploratory way and 11.2% actively 'building' a possible solution (in a total of 4 minutes, 1 second). P9 & P10 (the slowest of the successful solves) spent only 19% of their time 'Not-Touching', 37% 'Touching', and 44% of their time 'Building'.

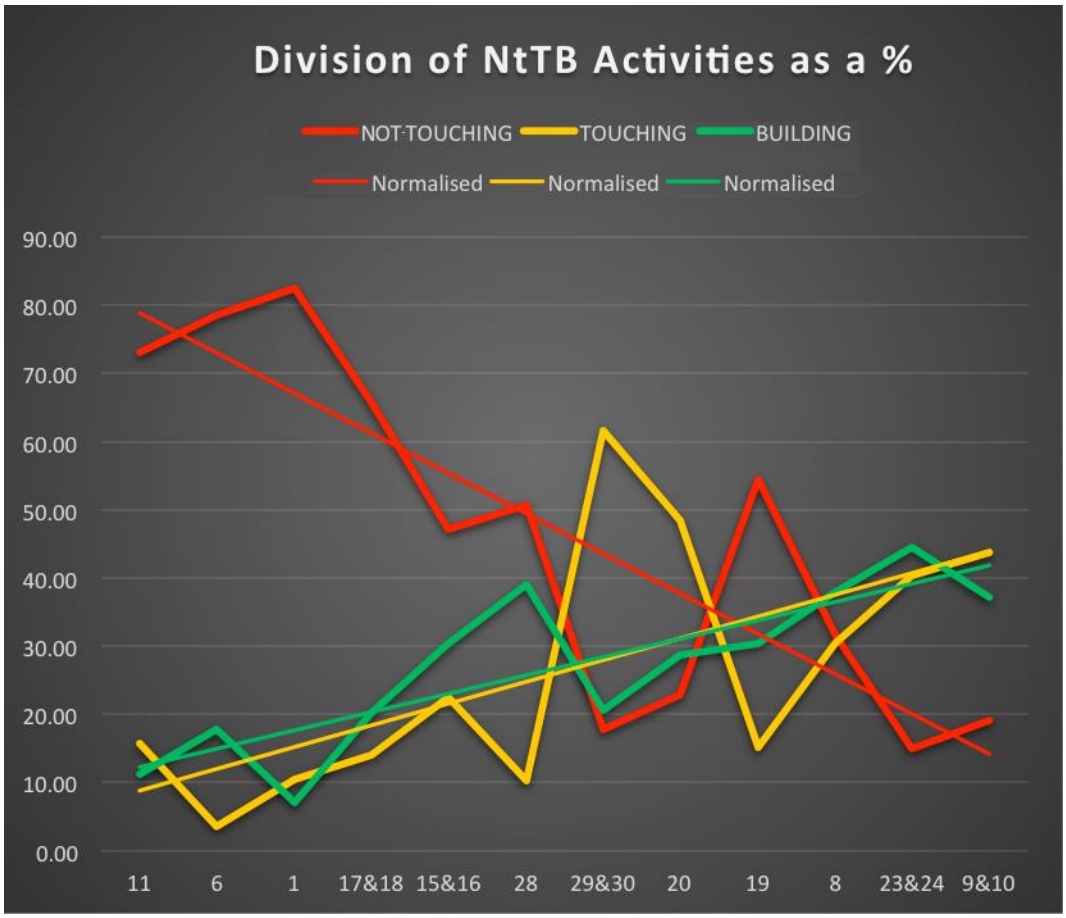


Figure 134 The Smuggling Scarecrow: NtTB Activities (%)

Hypotheses:

1. $H_{0:}$ There are no statistical variances between 'Not-Touching', 'Touching' and 'Building'.
2. $H_{A:}$ There are statistical variances between 'Not-Touching', 'Touching' and 'Building.

‘Not-Touching’, ‘Touching’ and ‘Building’ are separate activities and are independent of each other. A participant could have never touched, or always been touching a puzzle, but only one activity at a time.

The ANOVA results of those that solved The Smuggling Scarecrow puzzle were as follows:

1. There was a statistically significant difference between the groups as determined by one-way ANOVA ($F(2,33) = 0.449$, $p = .6419$).

In general, if the calculated F value (.45) is smaller than the F crit (3.28), so I cannot reject the null hypothesis. The large p-value (0.64) reinforces this. So, the null hypothesis that there were no statistically significant variances in ‘Not-Touching’, ‘Touching’ and ‘Building’ between the students who solved The Smuggling Scarecrow puzzle cannot be rejected.

Because of this result, there is no need for any post-hoc testing.

B4.2 The Smuggling Scarecrow: Clarification/Encouragement/Silence (CES)

Here, P11 spent 10 minutes and 1 second solving the puzzle, in complete silence. P6 required clarification for 50 seconds, but otherwise just focussed on solving it, see Figure 135 below.

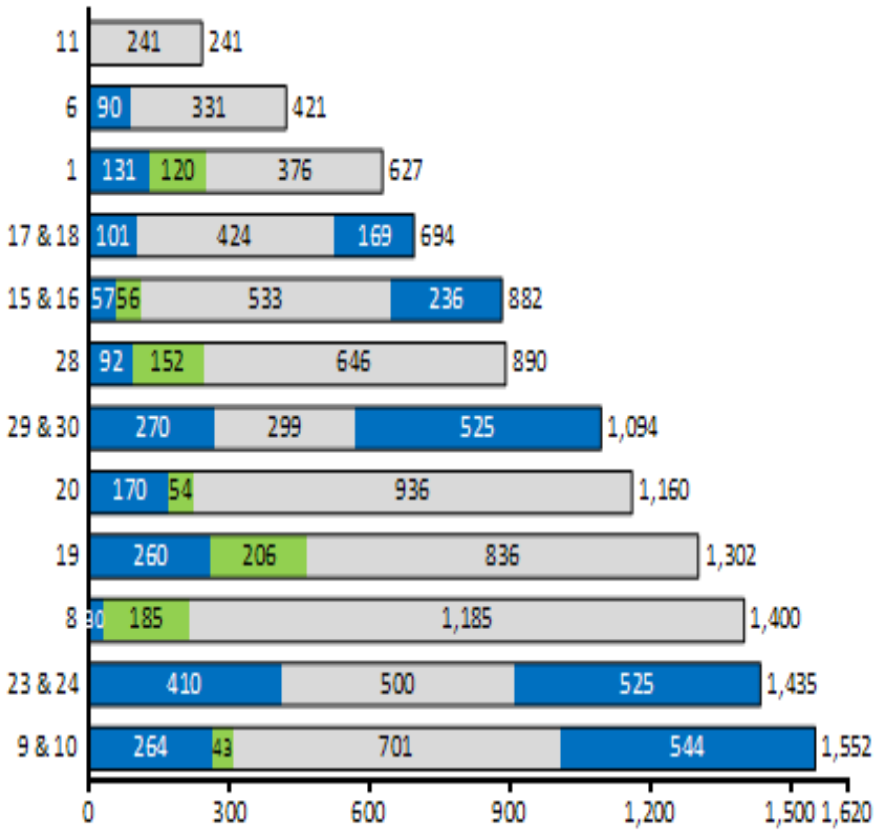


Figure 135 The Smuggling Scarecrow CES Solve Results

Figure 136, see below, is a breakdown of the same participants.

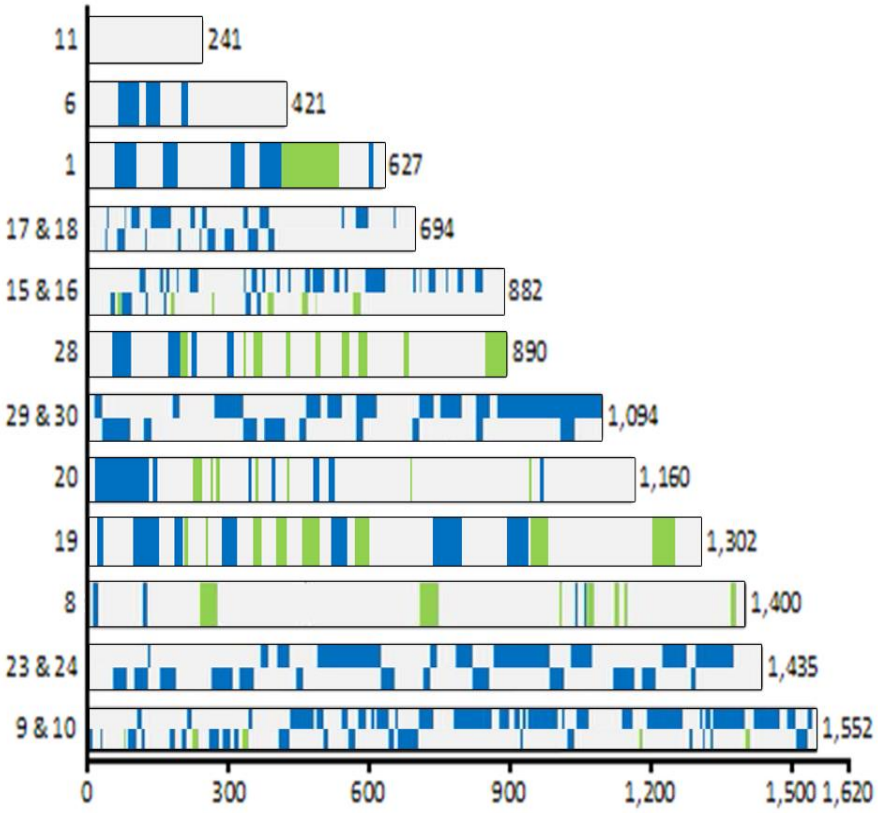


Figure 136 The Smuggling Scarecrow CES Breakdown

Figure 137 below, presents the same information, but with all activities presented in percentages. Fastest solve is on the left, (P11), second fastest (P6) is next, etc. P11 spent 100% of his time in silence, ignoring the Facilitator's presence. P29 & P30 spent 27% of their time in silence, and 73% of their time getting 'clarification', interacting twice as much with each other as they did with the Facilitator.

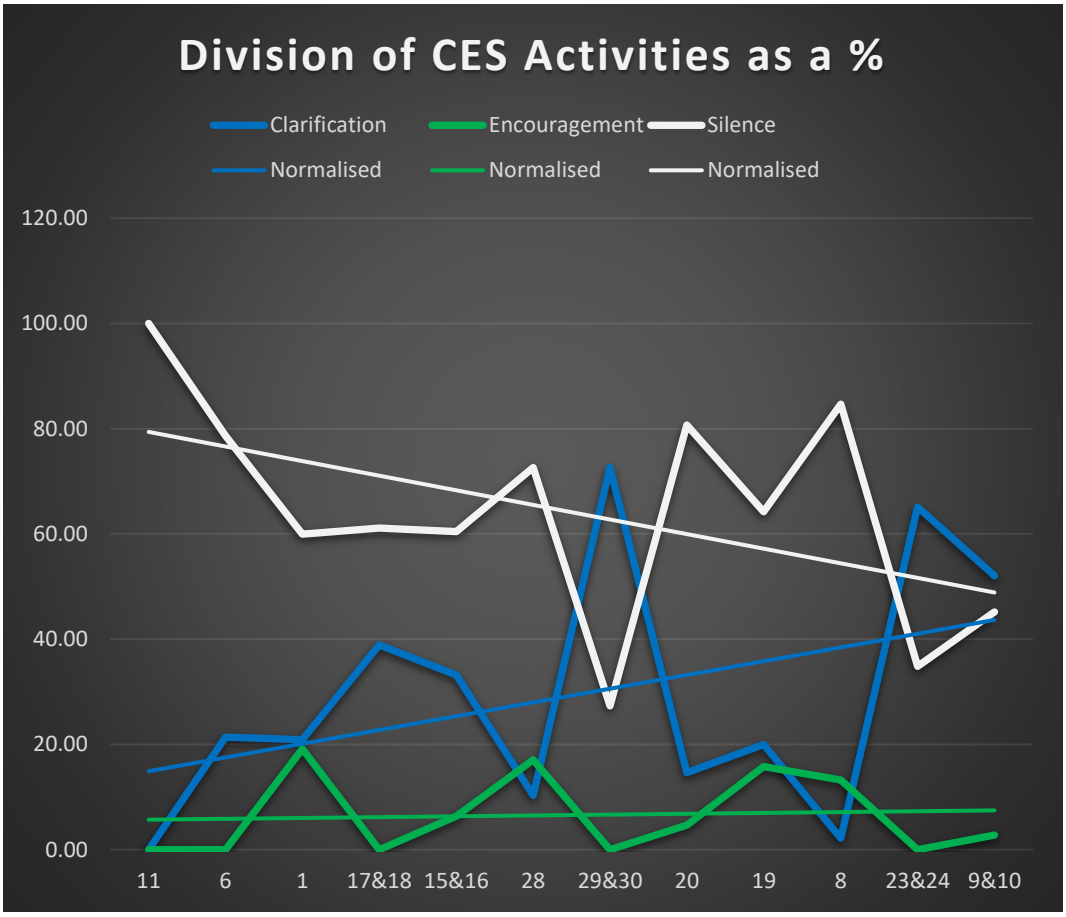


Figure 137 The Smuggling Scarecrow CES Activities (%)

Hypotheses:

1. $H_{0:}$ There are no statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.
2. $H_{A:}$ There are statistically significant variances between 'Clarification', 'Encouragement' and 'Silence'.

‘Clarification’, ‘Encouragement’ and ‘Silence’ are separate activities and are independent of each other. A participant could have never touched, or always been touching a puzzle, but only one activity at a time.

The ANOVA results of those that solved The Smuggling Scarecrow puzzle were as follows:

1. There was a statistically significant difference between the groups as determined by one-way ANOVA ($F(2,33) = 13.07$, $p = 6.59^{-5}$).

In general, if the calculated F value (13.07) is larger than the F crit (3.28), you can reject the null hypothesis, with the p-value reinforcing this. So, the null hypothesis that there are no statistical variances between ‘Clarification’, ‘Encouragement’ and ‘Silence’ with those who solved The Smuggling Scarecrow puzzle can be rejected.

A post-hoc test revealed that there remained a statistically significant difference between the:

1. ‘Clarification’ and ‘Engagement’ grouping ($F(1,22) = 6.729$, $p = 0.0165$).
2. ‘Encouragement’ and ‘Silence’ grouping ($F(1,22) = 36.079$, $p = 4.8^{-6}$).
3. ‘Clarification’ and ‘Silence’ grouping ($F(1,22) = 5.215$, $p = 0.032$).

While there was a mixture of silence, clarification and encouragement between them and the Facilitator, there was not a single instance of the participants encouraging each other.

Four of the pairs were each other’s best friends, so it must be acknowledged that some communications through the subtle body language that develops between close friends may have escaped undetected. But, a repeated listening to the clear speech (and the mumblings) of the participants revealed nothing that could be classed as encouragement. This was across 2,670 minutes, or 16,200 seconds, the standard unit used all along.

Charts were produced that included all puzzle attempts. Figure 138, see below, is a chart of all attempts with The Smuggling Scarecrow. But, over half of the activities represented in this example were unsuccessful solve attempts (the bottom-half). For those that did not solve, putting them in any order meant a subjective decision about which attempts were ‘better’, a decision based on how close they were to solving or, at least how close they were to understanding the problem.

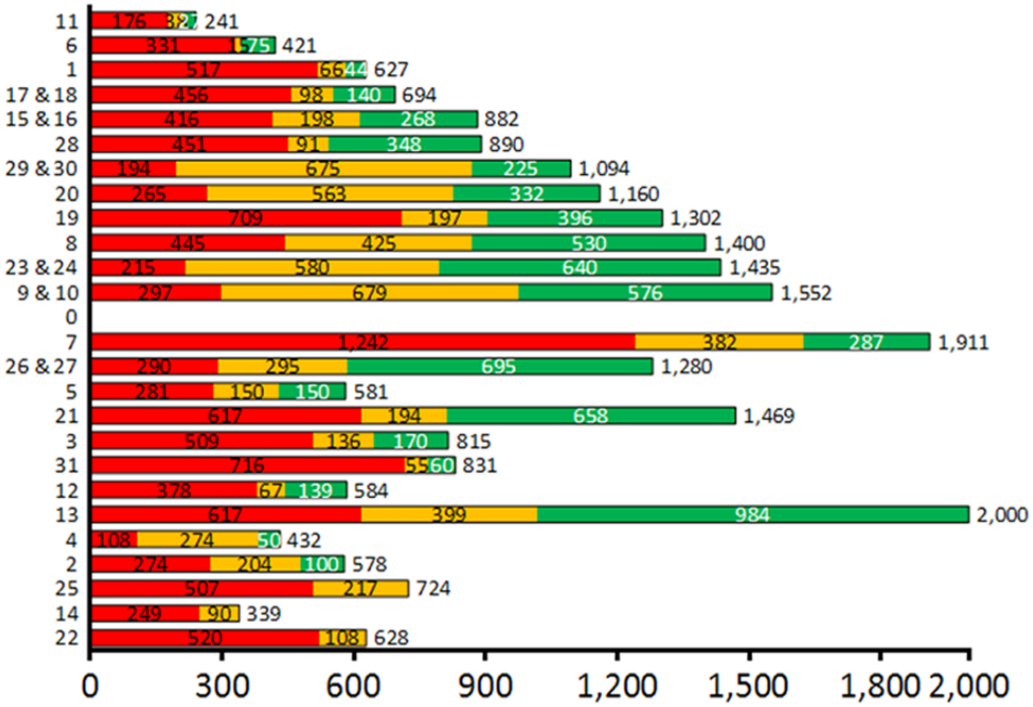


Figure 138 The Smuggling Scarecrow, all attempts NtTB, extended

It is not that those who didn’t solve a puzzle were discounted as irrelevant to an analysis. Their opinions and viewpoints were equally valid, and no such distinctions were made during the thematic analysis. But, including unsuccessful attempts would have created misleading findings, as many of the failed attempts with The Smuggling Scarecrow were at a conceptual level, many not getting anywhere with the puzzle and floundering before moving on.

Table 103, see below, presents the original ANOVA statistical findings, and also the findings that result from including all attempts.

Patterns in 'Not-Touching', 'Touching' and 'Building' for The Smuggling Scarecrow	
Between all Solves	($F(2,33) = 0.449$, $p = 0.642$)
Between all Attempts	($F(2,63) = 66.194$, $p = 3.28^{-16}$)

Table 103 Comparison between Solves & Attempts

The p-value of 0.642 is representative of the physical patterns of participants who were making focussed efforts, of the repetitive patterns in physical behaviour between those who solved The Smuggling Scarecrow. The behaviour was repetitive because of the limited manipulations possible with that puzzle.

The other p-value (3.28^{-16}) is not representative of everyone's efforts in any meaningful, coherent way. This is why the statistical analysis was focussed on the successful attempts for each puzzle. The thematic analysis discussed in section 5.4 will provide detailed insight about how the pedagogical experience affected all of the participants, regardless of any 'performance'.

B5 The Academic Motivation Scale

This appendix contains the complete Academic Motivation Scale, and the raw data from participants completing this survey, see Figure 139 & 140 below.

Then, the calculated results from this raw data will be presented in full.

Using the scale below, indicate to what extent each of the following items presently corresponds to one of the reasons why you study design.

Does not correspond at all		Corresponds a little		Corresponds moderately		Corresponds a lot		Corresponds exactly
1	2		3	4	5		6	7

WHY DO YOU STUDY DESIGN? **(ENGAGEMENT)**

1. Because without a degree, I would not find a high-paying job later on.	1	2	3	4	5	6	7
2. Because I experience pleasure and satisfaction while learning new things.	1	2	3	4	5	6	7
3. Because I think that a college education will help me better prepare for the career I have chosen.	1	2	3	4	5	6	7
4. For the intense feelings I experience when I am communicating my own ideas to others.	1	2	3	4	5	6	7
5. Honestly, I don't know; I really feel that I am wasting my time in college.	1	2	3	4	5	6	7
6. For the pleasure I experience while surpassing myself in my studies.	1	2	3	4	5	6	7
7. To prove to myself that I am capable of completing my college degree.	1	2	3	4	5	6	7
8. In order to obtain a more prestigious job later on.	1	2	3	4	5	6	7
9. For the pleasure I experience when I discover new things never seen before.	1	2	3	4	5	6	7
10. Because eventually it will enable me to enter the job market in a field that I like.	1	2	3	4	5	6	7
11. For the pleasure that I experience when I read interesting authors.	1	2	3	4	5	6	7
12. I once had good reasons for going to college; however, now I wonder whether I should continue.	1	2	3	4	5	6	7
13. For the pleasure that I experience while I am surpassing myself in one of my personal accomplishments.	1	2	3	4	5	6	7
14. Because of the fact that when I succeed in college I feel important.	1	2	3	4	5	6	7

Figure 139 The AMS Part 1

Using the scale below, indicate to what extent each of the following items presently corresponds to one of the reasons why you study design.

Does not correspond at all		Corresponds a little		Corresponds moderately		Corresponds a lot		Corresponds exactly
1	2	3	4	5	6	7		

WHY DO YOU STUDY DESIGN? **(ENGAGEMENT)**

15. Because I want to have "the good life" later on.	1	2	3	4	5	6	7
16. For the pleasure that I experience in broadening my knowledge about subjects which appeal to me.	1	2	3	4	5	6	7
17. Because this will help me make a better choice regarding my career orientation.	1	2	3	4	5	6	7
18. For the pleasure that I experience when I feel completely absorbed by what certain authors have written.	1	2	3	4	5	6	7
19. I can't see why I go to college and frankly, I couldn't care less.	1	2	3	4	5	6	7
20. For the satisfaction I feel when I am in the process of accomplishing difficult academic activities.	1	2	3	4	5	6	7
21. To show myself that I am an intelligent person.	1	2	3	4	5	6	7
22. In order to have a better salary later on.	1	2	3	4	5	6	7
23. Because my studies allow me to continue to learn about many things that interest me.	1	2	3	4	5	6	7
24. Because I believe that a few additional years of education will improve my competence as a worker.	1	2	3	4	5	6	7
25. For the "high" feeling that I experience while reading about various interesting subjects.	1	2	3	4	5	6	7
26. I don't know; I can't understand what I am doing in school.	1	2	3	4	5	6	7
27. Because college allows me to experience a personal satisfaction in my quest for excellence in my studies.	1	2	3	4	5	6	7
28. Because I want to show myself that I can succeed in my studies.	1	2	3	4	5	6	7

Figure 140 The AMS Part 2

Figure 141, below, is the key for the AMS.

KEY FOR AMS (Academic Motivation Scale)

# 2, 9, 16, 23	Intrinsic motivation - to know
# 6, 13, 20, 27	Intrinsic motivation - toward accomplishment
# 4, 11, 18, 25	Intrinsic motivation - to experience stimulation
# 3, 10, 17, 24	Extrinsic motivation - identified
# 7, 14, 21, 28	Extrinsic motivation - introjected
# 1, 8, 15, 22	Extrinsic motivation - external regulation
# 5, 12, 19, 26	Amotivation

Figure 141 The AMS Key

Participants 1-31 are presented on the following pages in Tables 104-112, with their responses to Statements 1-28 on the Academic Motivation Scale.

The colour coding is this researcher's own, to group the statements. For example, Green codes/groups the answers 2, 9, 16, & 23; and all are related to the category: 'Intrinsic Motivation – to know'.

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P1	5	6	6	5	1	3	1	5	4	6	5	1	3	3
P2	7	5	5	4	1	5	4	7	6	6	3	1	4	5
P3	6	2	7	1	1	1	2	7	1	7	1	1	1	1
P4	6	5	5	2	2	4	4	6	3	6	1	2	5	4
P5	7	7	6	4	1	6	5	7	5	7	5	1	6	6
P6	6	4	7	1	1	1	3	6	1	7	1	1	3	5
P7	6	7	4	3	1	6	6	5	6	5	3	4	6	2
P8	5	6	7	4	2	3	3	4	5	6	2	1	2	4
P9	4	7	7	5	1	7	4	4	7	7	7	1	7	4
P10	5	6	6	6	1	4	3	5	5	6	7	2	5	5
P11	6	3	6	4	1	3	2	6	2	5	1	1	4	2
P12	6	5	6	3	1	5	6	5	4	7	2	4	5	6
Participant	15	16	17	18	19	20	21	22	23	24	25	26	27	28
P1	5	4	4	4	1	4	4	6	6	5	4	1	2	3
P2	6	6	5	2	1	4	3	7	5	7	4	1	5	6
P3	7	2	4	1	1	1	1	7	3	5	3	1	1	1
P4	7	4	4	1	1	3	4	6	5	4	2	1	3	6
P5	6	6	5	4	1	7	7	7	6	7	5	1	6	6
P6	7	5	5	1	1	5	5	7	6	7	2	1	3	7
P7	5	6	6	3	2	4	2	3	3	2	2	2	2	2
P8	3	4	6	4	1	2	2	3	5	6	2	2	4	2
P9	1	7	6	5	1	7	4	4	5	6	5	1	4	5
P10	5	6	5	5	1	5	3	6	6	6	6	2	6	5
P11	6	4	2	2	1	5	5	6	4	5	1	1	4	3
P12	5	4	3	1	4	5	6	6	4	5	1	1	5	5

Table 104 AMS Results for P1-P12

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P13	6	5	7	4	1	5	7	6	6	5	4	1	4	6
P14	7	6	7	5	1	7	7	7	6	7	6	1	6	4
P15	6	6	7	5	4	6	6	6	6	5	4	6	7	7
P16	6	5	6	5	1	5	6	6	4	6	2	1	6	3
P17	4	4	5	5	1	1	1	5	4	7	3	1	4	2
P18	4	3	7	7	1	4	7	7	7	6	3	5	7	6
P19	5	7	5	3	1	4	5	7	6	7	6	1	4	5
P20	6	7	6	5	1	6	7	5	7	5	4	2	7	1
P21	4	5	6	6	1	5	3	5	7	7	4	1	5	1
P22	5	6	6	5	2	4	3	5	5	6	4	2	6	4
P23	6	6	5	3	1	4	7	7	6	7	5	1	2	5
P24	7	7	7	4	1	5	4	5	7	7	7	1	5	5
Participant	15	16	17	18	19	20	21	22	23	24	25	26	27	28
P13	6	6	5	4	1	5	4	6	6	5	5	1	5	6
P14	5	6	6	6	1	6	4	6	6	6	5	1	5	6
P15	6	7	5	4	2	6	6	6	6	5	5	2	5	7
P16	5	6	6	1	1	4	2	6	6	4	1	1	6	6
P17	5	6	6	5	1	7	3	5	6	6	4	1	5	6
P18	6	7	6	5	1	6	7	7	6	7	3	1	6	7
P19	6	7	7	4	1	5	4	6	7	6	5	1	6	4
P20	1	6	5	5	1	5	4	7	7	7	6	1	7	5
P21	5	6	5	4	1	5	1	5	7	6	4	1	5	5
P22	6	5	6	5	1	5	4	6	6	7	4	1	4	6
P23	7	7	4	3	1	4	2	6	7	3	3	1	5	6
P24	7	7	6	6	1	5	6	6	6	6	4	1	4	5

Table 105 AMS Results for P13-P24

Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P25	7	5	6	4	2	3	5	7	7	7	5	3	4	4
P26	5	6	6	3	1	4	2	4	6	6	2	1	5	4
P27	4	5	6	5	3	4	6	6	6	6	3	4	6	5
P28	6	6	6	5	1	6	7	6	7	6	4	2	5	5
P29	7	4	7	6	1	4	6	7	6	7	1	1	6	5
P30	7	3	7	2	1	4	7	7	5	7	2	4	4	3
P31	4	7	6	2	1	7	7	6	3	7	1	1	7	7
Participant	15	16	17	18	19	20	21	22	23	24	25	26	27	28
P25	7	4	6	4	2	3	4	7	5	6	4	1	3	4
P26	4	5	6	2	1	4	3	6	6	6	2	1	5	4
P27	6	6	6	4	1	4	4	6	6	5	4	1	6	5
P28	5	6	6	4	1	5	5	5	6	6	4	1	6	6
P29	7	6	7	2	1	6	4	7	7	7	4	1	5	5
P30	6	5	6	2	4	4	6	7	4	7	1	4	3	7
P31	5	7	7	1	1	6	6	6	7	7	2	1	6	7

Table 106 AMS Results for P25-P31

Participants 1-31 are presented on the following pages with their calculated scores from the Academic Motivation Scale.

Participant	IM - to know	%	IM - toward accomplishment	%	IM - to experience stimulation	%
P1	20	66.7	12	33.3	18	58.3
P2	22	75.0	18	58.3	13	37.5
P3	8	16.7	4	3.3	6	8.3
P4	17	54.2	15	45.8	6	8.3
P5	24	83.3	25	87.5	18	58.3
P6	16	50.0	12	33.3	5	4.2
P7	22	75.0	18	58.3	11	29.2
P8	20	66.7	11	29.2	12	33.3
P9	27	95.8	19	62.5	18	58.2
P10	27	95.8	25	87.5	20	66.6
P11	13	37.5	16	50.0	8	16.7
P12	17	54.2	20	66.7	7	12.5

Table 107 AMS Intrinsic Scores for P1-P12

Participant	EM - identified	%	EM - introjected	%	EM - external regulation	%	Amotivation	%
P1	21	70.8	11	29.2	21	70.8	4	0.0
P2	23	79.2	18	58.3	27	95.8	4	0.0
P3	23	79.2	5	4.2	27	95.8	4	0.0
P4	19	62.5	18	58.3	25	87.5	6	8.3
P5	25	87.5	24	83.3	27	95.8	4	0.0
P6	26	91.7	20	66.7	26	91.7	4	0.0
P7	17	54.2	12	33.3	19	62.5	9	20.8
P8	25	87.5	11	29.2	15	45.8	6	8.3
P9	25	87.5	18	58.2	24	83.3	4	0.0
P10	23	79.2	17	54.1	19	62.5	5	4.2
P11	18	58.3	12	33.3	24	83.3	4	0.0
P12	21	70.8	23	79.2	22	75.0	10	25.0

Table 108 AMS Extrinsic Scores for P1-P12

Participant	IM - to know	%	IM - toward accomplishment	%	IM - to experience stimulation	%
P13	23	79.2	19	62.5	17	54.2
P14	24	83.3	24	83.3	22	75.0
P15	25	87.5	20	66.7	18	58.2
P16	22	75.0	19	62.5	18	58.2
P17	26	91.7	15	45.8	14	41.6
P18	27	95.8	19	62.5	21	70.7
P19	27	95.8	19	62.5	18	58.3
P20	27	95.8	25	87.5	20	66.7
P21	25	87.5	20	66.7	18	58.3
P22	22	75.0	19	62.5	18	58.3
P23	23	79.2	20	66.7	16	49.9
P24	25	87.5	22	75.0	17	54.1

Table 109 AMS Intrinsic Scores for P13-P24

Participant	EM - identified	%	EM - introjected	%	EM - external regulation	%	Amotivation	%
P13	22	75.0	23	79.2	24	83.3	4	0.0
P14	26	91.7	21	70.8	25	87.5	4	0.0
P15	24	83.3	10	25.0	19	62.5	4	0.0
P16	25	87.5	17	54.1	22	75.0	6	8.3
P17	19	62.5	20	66.6	26	91.7	4	0.0
P18	26	91.7	20	66.6	25	87.5	4	0.0
P19	25	87.5	18	58.3	24	83.3	4	0.0
P20	23	79.2	17	54.2	19	62.5	5	4.2
P21	24	83.3	10	25.0	19	62.5	4	0.0
P22	25	87.5	17	54.2	22	75.0	6	8.3
P23	23	79.2	20	66.6	22	75.0	9	20.8
P24	24	83.3	23	79.0	22	75.0	5	4.2

Table 110 AMS Extrinsic Scores for P13-P24

Participant	IM - to know	%	IM - toward accomplishment	%	IM - to experience stimulation	%
P25	21	70.8	13	37.5	17	54.2
P26	25	87.5	22	75.0	17	54.1
P27	23	79.2	21	70.8	13	37.4
P28	25	87.5	22	75.0	17	54.2
P29	23	79.2	21	70.8	13	37.4
P30	17	54.2	15	45.8	7	12.5
P31	24	83.3	26	91.7	6	8.3

Table 111 AMS Intrinsic Scores for P25-P31

Participant	EM - identified	%	EM - introjected	%	EM - external regulation	%	Amotivation	%
P25	25	87.5	17	54.2	28	100.0	8	16.7
P26	24	83.3	23	79.0	22	75.0	5	4.2
P27	28	100.0	20	66.6	28	100.0	4	0.0
P28	24	83.3	23	79.2	22	75.0	5	4.2
P29	28	100.0	20	66.6	28	100.0	4	0.0
P30	27	95.8	23	79.0	27	95.8	13	37.5
P31	27	95.8	27	95.8	21	70.8	4	0.0

Table 112 AMS Extrinsic Scores for P25-P31

Appendix C

This appendix contains any correspondence with my participants, and the transcripts of their interviews.

Appendix C1 contains the ethics forms that the participants signed.

Appendix C2 contains the invitation email for interview and the attached questions.

Appendix C3 contains the interview transcripts.

Appendix C4 contains the Thematic Analysis documentation.

C1 Ethics Forms

FACULTY OF SCIENCE AND ENGINEERING

RESEARCH ETHICS COMMITTEE
INFORMATION SHEET

Dear Participant,

My name is Alan Ryan and I am currently undertaking a PhD at the University of Limerick under the supervision of Dr. Mikael Fernström. The title of my proposed research is "Thinking with your Hands: Understanding Design". The purpose of this project is to explore new methods for teaching design, specifically examining if solving physical Insight Puzzles can assist a student's comprehension of abstract design concepts.
You are being asked to attend a brief lecture (5 minutes), attempt to complete 3 Insight Puzzles (45 minutes), complete a survey (10 minutes), and then participate in a semi-structured interview with the researcher. The interview should take approximately 30-45 minutes.
The short lecture, puzzle-solving activity, survey and subsequent interview will take place in the CSIS Building, all within a 2 hour time-frame. The lecture and puzzle-solving activity will be recorded via video, primarily for review purposes so that any information that may have been overlooked by the researcher at the time of the interview can be examined again. The interview will be recorded via audio, for the same reason. However if you should feel uncomfortable at any stage during the interview, the recording equipment can be turned off. There are no foreseeable risks in taking part in this study. All names and data will be anonymised throughout the study. Participants will be referred to as User1, User2, etc.

Thank you for taking part in this study, your participation is voluntary and you have the right to withdraw from this study at any time. If you have any concerns or are unhappy with the manner in which the study was conducted, please contact Dr. Mikael Fernström or the Chair of Faculty of Science and Engineering Research Ethics Committee, Dr. Thomas Waldmann. Both contacts are available below.

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FACULTY OF SCIENCE AND ENGINEERING

RESEARCH ETHICS COMMITTEE
INFORMATION SHEET

Consent Section:

I, the undersigned, declare that I am willing to take part in research for the project entitled "Thinking with your Hands: Understanding Design".

- I declare that I have been fully briefed on the nature of this study and my role in it and have been given the opportunity to ask questions before agreeing to participate.
- The nature of my participation has been explained to me and I have full knowledge of how the information collected will be used.
- I am also aware that my participation in this study may be recorded (video/audio) and I agree to this. However, should I feel uncomfortable at any time I can request that the recording equipment be switched off. I am entitled to copies of all recordings made and am fully informed as to what will happen to these recordings once the study is completed.
- I fully understand that there is no obligation on me to participate in this study.
- I fully understand that I am free to withdraw my participation at any time without having to explain or give a reason.
- I am also entitled to full confidentiality in terms of my participation and personal details.

_____ _____

Signature of participant Date

C2 Interview Invitation, Questions and Transcripts

Post puzzle solving, participants returned for an individual interview. Arrangements for the interview were made through email.

Hi [name of participant],

Thank you so much for participating in my PhD research. As you know, I am testing whether several theories regarding Student Engagement are applicable to Design Students, through your attempts to solve tangible Insight Puzzles and your opinions about that activity.

I've reviewed the video of your puzzling-solving activity and would now like to arrange a time for our follow-up interview. I am teaching 11-12 on Mondays and 12-1 on Fridays. I will have some commitments that change from week to week (class preparation/one-off lectures), but I am generally free excepting those times.

So, please pick a time that suits you. I will respond ASAP to confirm. I expect the interview to last about 30 minutes (or longer if you are feeling very chatty!). The questions are attached as a courtesy, but I would like to remind you now that there can be no "wrong answers". What I want (and need) are your honest opinions, regardless of whether you liked/loved/hated the whole experience!

Some of the questions may seem repetitive, but they do address the subtlety distinct aspects of the body of research regarding Student Engagement.

I hope to get these 30+ interviews completed before you all get too busy with your own assignments, so let me know when you are available.

Again, thank you so much.

Alan

The following interview questions were attached with this email. There were two variations, depending or whether participants had arrived alone, or in a pair.

Questions for Students

1. How long have you been studying design?
2. What's your favourite designed object/thing? Why?
3. Do you have different levels of enthusiasm depending on the subject being studied? Why?
4. What do you think defines a successful student?
5. What do you think defines a successful instructor?
6. Why did you volunteer for this testing with me?

7. How do you think the physical nature of the puzzles affected your reasoning?
8. How do you think the physical nature of the puzzles affected your emotional engagement?

9. How did (Working in Pairs/Working Alone) affect your thinking?
10. How did (Working in Pairs/Working Alone) affect how you felt?
11. Would you have preferred (Working in Pairs/Working Alone)? Why?
12. Were you comfortable with voicing your opinion? (Pairs Only)

13. How did you feel about dealing with physical puzzles in a learning environment?
14. How did you feel about your performance with the puzzles?
15. What would you have done differently?

16. How did the choice element, the ability to direct your learning, affect your thinking?
17. How did the choice element, the ability to direct your learning, affect how you felt?

18. What was your favourite aspect of learning like that?
19. What was your least favourite aspect of learning like that?

20. Did you learn anything useful to you? What?
21. Did you learn anything that was interesting to you, and not just useful to know? What?

22. Do you think that your learning experience helped you to more fully understand Problem Re-framing?
23. Do you care?
24. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?

C3 Interview Transcripts

C3.1 P1 Transcript

P1: Single: DMD 4th Year

1. How long have you been studying design?
P1: Well, 4 years. That's my 4th year now. So, I haven't really, I don't think it has been proper design in a way because we've been in such like…there has been so many different modules which haven't been really related straight to design, which is…that's why I haven't thought I started studying design until I went on CoOp and that's where I got lectures from my boss on "what's this?" and "what's that?" He asked me "what's design?" and I had no clue what to say. I just blanked, I said "what is design?"
RESEARCHER: Where do you go for CoOp?
P1: I went to SAP in Dublin so, it was…I studied for 4 years, but I haven't really felt it until the 3rd year, in CoOp.

2. What do you think defines a successful student?
P1: Not really grades, as in your understanding of what you're studying, so if you can tell someone that has no clue about what you're doing, and you can say it in simple words and the other person knows what you're talking about and understands it, that's what a successful student is, that they understand what they're learning.

3. What do you think defines a successful instructor?
P1: That's a tough one. Cos it depends on how the student learns really. I learn by doing and looking at something and going over something over and over again. Some people can listen to a lecture for a few minutes and they understand. I think they just have to be engaging and have to kind of...think up of examples of something new every day rather just have like read off a slideshow "this is how you're supposed to do it" cos they know how to do it and they're supposed to be teaching someone else how to do it. So they have to come up with something engaging that will make you just go "oh, this is interesting. I want to learn more about that."
RESEARCHER: When that happens, how do you react?
P1: Well, if it's engaging I go to the lectures. I go, I take notes, I listen and then I kind of look it up on the Internet, look up different people that are interested in the same topic, whereas if the instructor is boring and they just read of the slideshow, sometimes I don't bother, I know it's bad, but I just don't go to the lectures. I just don't. I just think I'm just going to read the slideshow and just do the assignments that way.

4. Why did you volunteer for this testing with me?
P1: It thought it was intriguing, I was interested, as soon as you said puzzles, I said "yes". I want to do this and I wanted to see if I'll be able to do it with my knowledge of design, and you kind of made me do it, haha...

5. How do you think the physical nature of the puzzles affected your reasoning?
P1: Thinking back on doing it, I don't remember what you said to me, you know the 5 minutes you talked, I don't remember anything, but to this day I remember what the puzzles are, how they work, and the meaning behind them, why they're there. So that's how I kind of learn, when it's in front of me and I can touch it, and I can play around

with it, so it definitely helped more than if you asked me a couple of questions and told me to answer them after listening to a video, or something.
RESEARCHER: The way you were reasoning, the way you were thinking, did you find it easier if you had things in your hand?
P1: 100%.
RESEARCHER: That's you, is it?
P1: Yeah. Even holding the little pieces, the pieces that are separate that you're meant to build something with them, even holding them, and looking around with them, and playing with them, sometimes I'd put something together and it clicked, "oh, that's how I should do it!", so it was nice to have something in my hands and move it around. I think that helped me a lot.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P1: So, I was more involved in it, and I wanted to get it finished, I wanted to solve them and I was kinda excited by them, whereas if I'm in a lecture, I'm just sitting there and thinking about when it's going to end and look at the clock and think I have to go home soon, but in this one, this is kinda exciting. I like puzzles too, so.
RESEARCHER: That's why you like puzzles? Have you always liked them?
P1: Yes.
RESEARCHER: Just thinking about the physical nature and your reasoning. Why do you think that was? Do you have any idea? It was in your hands, you were fiddling. Looking at the video, I can see you doing that a lot while you're looking at the puzzle, you've got bits in your hand. Any idea why?
P1: I think, when I was thinking of how to solve them, I was thinking of it in my head. If I do this, that's how it's gonna go, so if I was holding a bit in my hand, I was thinking what I could do, rather than just sitting down and thinking about it from afar, holding and fiddling with it, it helped me imagine how it could help and work.

7. How did "Working Alone" affect your thinking?
P1: Well I was thinking out loud, so I was talking to myself a lot, so it was kinda like having someone else, but at the same time, I was,...I don't know…I don't really think I would have minded having someone else, but at the same time I like working alone, I like doing things by myself, I think...it's such a hard question. I think, because I worked alone, it helped me work on my own time and I could move around the 3 puzzles and do everything by myself, do a bit here, but if I don't know what to do next, I can move and jump from puzzle to puzzle, I can make my little mess in my head, work with my hands and that's really it.

8. How did "Working Alone" affect how you felt?
P1: I was talking out loud, and I just felt like I have to finish it and I knew it's my own, I don't have anyone to ask questions and to help me, I did have the little clues, but it was kinda like a challenge, and I felt I was challenged that I had to do it, I was kinda motivated by myself.
RESEARCHER: You didn't have to do it.
P1: But that's how I was thinking about it. A little challenge. If I don't finish it, it would be kinda sad.

9. Would you have preferred "Working in Pairs"? Why?
P1: See, I like doing things on my own because I'm kind of. Even if I do a project I tell people what to do with some people don't like, but I'm that type of person I like to tell people "you do this part, I'll do this part, some else do this part", It would have to be a person that liking being told what to do. Otherwise, if it was [with] another person, it would be a mess and we would just end up not finishing anything.

[REFERRING TO VIDEO NOTES]
RESEARCHER: With the clues, you accessed every one of them.
P1: Yeah.
RESEARCHER: Why did you want to access the clues?
P1: In my head, I actually thought the clues would be different, I was expecting a clue to be a certain way, so then when I opened them I was kinda disappointed cos none of them were the way I wanted to be and they confused me, and then I kinda regretting opening them all. I was just hoping that the clues will just kinda, that the clues were different from what they were. in my head I had some ideas "this clue will tell me how to do the whole thing", although the clue wasn't helping my idea of how it's gonna work, so that's why it was confusing for me so I wish I hadn't opened them.
RESEARCHER: OK. Would you have felt that you had performed better, (cos you solved all 3), so would you have seen it as more of an achievement if you hadn't looked at all the clues.
P1: Yes, although, I think for the last puzzle actually, the clues did help me a bit, because...
RESEARCHER: Which one was that?
P1: The one with The Batman.
RESEARCHER: The Scarecrow.
P1: Yeah. So, I feel like, for that one I was just kinda, I wasn't thinking outside the box for that one, so the clues did help me a bit. For the first two, I was just completely, they completely threw me off.
RESEARCHER: You were commenting things like, "I've already figured that out!" or "that just complicates things!"
P1: Yeah.

10. How did you feel about dealing with physical puzzles in a learning environment?
RESEARCHER: If this was a normal module and this was part of a deliverable, you had to turn up to try this?
P1: I think, I definitely would feel more excited about that kind of way of learning, because as I said, I remember doing this. And I did it first, so...
RESEARCHER: So, it was 2 months ago.
P1: I just, I remember everything I was doing and things I was saying, and how I felt. Whereas if you asked me about lectures I had even in the past few weeks, I would have no clue.
RESEARCHER: Today!
P1: I don't want to learn by hearing things. I want to see how things work. I know for a lot of lectures, it doesn't work, like you can't show people how things work, like for design it is a very much, you can show with everything, even HCI or User Experience, you can show everything. Yeah, I would feel so much more excited if lectures were like that.

11. How did you feel about your performance with the puzzles?
P1: I was happy that I finished them all. Like the time, the way it was ticking, it making me feel really excited, but I think that's just my competitive nature. I was happy, like as I said, if I had to go back again, I would not open any of the clues, because they just confused me, I had my way of thinking, I should have just stuck to that. So, I was happy.

12. What would you have done differently?
RESEARCHER: The next question is what you would have done differently. So, it would have been the clues?
P1: Yes, probably I would have spent more time...
RESEARCHER: So did you feel like you it was giving in?
P1: I did feel I was sick as well.
RESEARCHER: You were a bit. You were very brave.
P1: I think if I had just stuck to my ways of thinking, cos I was thinking and I had ideas. But, it was just like "Maybe I'm wrong", cos I was doubting myself a bit. I definitely would have... one clue.
RESEARCHER: Maybe 1 clue, to get you started.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P1: I liked that actually, cos when I saw all of them together, I didn't want to just do one, and do it fully and move on, I wanted to get a grasp of the whole thing first, and I didn't want to waste time on one thing, and then...in my head I think of a lot of things at the same time, and that's how I work best, so it was nice that I could go and read all of the puzzles and then…
RESEARCHER: Yeah, you stopped at The Lamp after reading a 2nd clue and not being that happy, as in it didn't help. You dropped it and went straight to The Lift.
P1: After the 2nd clue, my brain just stopped working, I didn't want to think about this, I want something new.
RESEARCHER: You solved The Lift in the one go, then you started on The Batman one, and then, after you accessed the clue on that one, you again stopped, and went to The Lamp cos The Lift was done and you skipped back and forth between them.
P1: It made my thoughts at the back of my head to be able to move around. It was just easier for me. I think I would have got really frustrated if I had to stick with one and move on. Simply because there was a time constraint, but at the same time it would have made me, if I can figure something out, I'm gonna go off and do something else with everything and if I didn't have that option there, I would have given up.
RESEARCHER: You were free to give up, but you were never going to do that.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P1: It was nice and I felt more, that I was more free to do it and I felt that I'm not under such pressure to finish one and then move on. Everything was really good, I didn't feel frustrated if I had to stick with one and finish it all the way through, so...
RESEARCHER: You did do that with one of them.
P1: Yeah, but that was because I knew I could do it, so I just wanted to do it and move on. It was the time, in the back of my head I was thinking "there's time, there's time". But I hadn't looked at the time until halfway through. So, I wasn't as frustrated as in sticking to one thing, I had the freedom to move around.

RESEARCHER: You weren't the only person to do this. You worked really quickly, quickly enough, how The Lamp worked, but then you ended up trying to build, what ended up being an overly complex mechanism than was possible. Why did you do that?
P1: In my head, I just thought it was more complicated than it is, I think I knew how to do it at the start, but in my head, that doubt "it's not that easy". I think that's with everything I'm doing, every assignment, every homework, "it can't be that easy", so that was in my head, at the back, this little voice "it's definitely not just that", so I was trying to take it apart...
RESEARCHER: In principle, it was similar to the actual simple solution, but you had this complex, almost like a spring mechanism built with different parts of the K'Nex. So, "wow!" I was thinking. So, it did work. It was the same principle you enacted, just the mechanism you built was really complex.

15. What was your favourite aspect of learning like this?
P1: I think my favourite bit was, I don't know if that's OK, but that there was some content behind it, there was a story, because if it was just a simple puzzle with no Batman at the top or anything, I probably wouldn't remember it as much, but because there was some fun aspects to it. I just enjoyed it. Because when I was explaining it to my mom "there was a Batman", it's kind of like a child thing, it was more exciting, I just remembered it more.

16. What was your least favourite aspect of learning like this?
P1: The clues.
RESEARCHER: Why?
P1: It was just all in my head, I had a different idea for what the clues were going to be like. I know the clues were good. And I know the clues, see if I hadn't thought of any of the solutions at the start and maybe saw the clue, then I would have thought of the thing from a certain point of view where the clue wanted me to go, but my brain just didn't go where the clues were going.

17. Did you learn anything useful to you? What?
P1: It was mostly the whole idea of, there is a problem, you can just add one small thing to just fix it, like the whole, what's it called, yeah, reframing, the reframing of a problem. It was interesting to see that these puzzles were something that is already out there in the world but not in that kind of content but it was a bit different. It was interesting and it did stick my head so hopefully I'll remember it.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P1: Yeah, I think it was just it was just interesting to see how you can show different design ways in just like a puzzle, because I would never think that you could... like, the little lecture you gave me before that, I didn't think you could do it in a puzzle, it wasn't something that would have thought off so it was interesting.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P1: At the start, I kinda had an idea of what it was, but I wasn't really, I wasn't fully aware, like if someone asked me, "yeah, maybe, I don't know", but after I had done

them, maybe if I had to apply it to an everyday thing, like at work or college, I think it'd be more it be easier for me to understand to do it, like apply it in the real world, so I think it did help, yes.

20. Do you care?
P1: I do care, cos this is gonna be, design, I want to work in design I think it'd be important to know any little bit of that, so yeah.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P1: Yeah, I think it was more like hands-on, which is not really what we've been doing for the past while, we are in university so it's mostly like assignments and stuff, it's very... it's like all about theory and stuff, but I think I never really done any of design thinking like hands-on, or like even when we were doing certain assignments where you had to make an app or stuff, it wasn't really like, I didn't feel like I'm fully doing design thinking, I think it was the first of all, it was really helpful, because this is what it is and I can apply to different things. I think I think it did help me, because it was like it showed me that design thinking is not just one thing, it could be like a variety of things, it could be in puzzles, in apps, in games, it helped.

C3.2 P2 Transcript

P2: Single: DMD 4th Year

1. How long have you been studying design?
P2: Approximately 4 years.

2. What do you think defines a successful student?
P2: As in "doing well?", or feels he's done enough?
RESEARCHER: You tell me.
P2: Well, for a person who has done enough, it's someone who has been able to manage interest in study, and able to accomplish all the projects. From the perspective of the Faculty, would be to be outstanding in every area which they've been trialled in.
RESEARCHER: What do you think? Forget about other people, I'm not writing a dictionary and going to fill in your responses.
REPEATS QUESTION
P2: A successful student is someone who has achieved, I believe if I have achieved something which I thought I couldn't achieve, so to get a 2:1, even though I always thought I'd only be able to get a 2:2.

3. What do you think defines a successful instructor?
P2: A success instructor? In my few years here, I've realised that some instructors have an interest in what they're teaching, and others don't. Does who do not have interest in what they are teaching, turn out to be not successful.
RESEARCHER: Why?

P2: Because if a lecturer does not have an enthusiasm in the area they are teaching, then that will not come across to the students to be interested in the area.
RESEARCHER: That's how you feel, this is not uncommon, but if someone clearly is just talking, and they don't care, do you start to not care then?
P2: Yes. For example, I had a lecturer recently, in 3rd Year, her enthusiasm was inspirational and addictive. It made you do better, and made you aim to please her as well to please yourself with assignments.
RESEARCHER: This is not an unusual opinion.

4. Why did you volunteer for this testing with me?
P2: Why did you ask that question? Is it needed?
RESEARCHER: Yes.
P2: You didn't exactly explain to me what this was about.
RESEARCHER: What did I explain?
P2: Will you do me a favour?
RESEARCHER: Were you perfectly happy to go along?
P2: Why not?

5. How do you think the physical nature of the puzzles affected your reasoning?
P2: Well, the physical nature of it, being kinetics, really helped really, cos it is something one is familiar of from a younger age, so that helped the "interest" part. Definitely hands-on is the main method for learning.
RESEARCHER: For you?
P2: For me specifically, even though I tend to learn a lot more from videos. I always used to watch "How it's made", on the Discovery Channel. I do think going it to start something is much better, cos I'm a believer that you don't learn anything in life if you don't make mistakes. If I have succeeded in all 3, I'd actually be more disappointed than if I'd successfully completed all 3. The nature of getting ahead and getting hands in first is a good concept for myself.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P2: It made me extremely angry.
RESEARCHER: Why?
P2: Because frustration kicked in approx. 7 minutes into it.
RESEARCHER: Approx. 7 minutes in!
P2: Yes. Which led to anger, then also just not getting to where you wanted to be.
RESEARCHER: But if it was a puzzle where I did a sketch on a whiteboard, and said "how would solve this?" would that have made you less frustrated and angry, or more?
P2: To sketch something?
RESEARCHER: If I did a sketch and you just had to think it through and give me an answer in English, what's the solution to this? There's no physical aspect to it then, it's all in your imagination. How does that affect you?
P2: That would be easier, as you can't test if you're just thinking about it. If it's something physical, you will have to go and "Can I do this?" and then go and do it, and then it doesn't work out. "Can I just do this?" OK, go do it. That doesn't work out. That means a more time consuming process, then just sitting there thinking about what you can do, while all you can do is just think about it.
RESEARCHER: And did, so that's less frustrating to do it, just mentally?
P2: Yes, because it's also a time process.

RESEARCHER: Why did you think it was more frustrating having it be physical? Was it just because of the time it took to test things?
P2: Yeah. Time is very important, Researcher.
RESEARCHER: Especially the limits you were under.

7. How did "Working Alone" affect your thinking?
P2: Well, thinking on my own, I felt all my decisions were mine, which is empowering. And also, it's nice to know when everything is your call, which it was.
8. How did "Working Alone" affect how you felt?
RESEARCHER: You were very quiet and deadly serious while you were doing them. Was that because you were on your own?
P2: No, that would be my human nature. Doing it by myself is just, I felt you could, it's just the feeling of knowing that if you make a mistake, it's your mistake. Feel in control, you know.

9. Would you have preferred "Working in Pairs"? Why?
P2: No.
RESEARCHER: OK.
P2: That's because of past experience in life. It wouldn't be because of the exercise.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You read through all 3 scenarios before touching anything. So, that was your way of doing it, some others did the same. You began with the lamp, you accessed the first two clues and then, eventually, took you a while, why didn't you access the clues? Well, you did make comments a couple of times, about feeling like it was a game and that your life was gone, like your 1st life was gone if you accessed the clue. Did you see it as a bad thing accessing the clues?
P2: Oh yes. As you keep mentioning yesterday, I'm a stubborn man. And accessing the clues, the cheats would only...
RESEARCHER: Saying "cheats" makes it sound like it was a bad thing. So, you wanted to do it without the clues?
P2: Yes.
RESEARCHER: That's fair. We're getting to that. You completed The Lift almost immediately. I think it was the fastest solve for any of the 3 puzzles by anybody. So no clues, cos you just did it. It was just so obvious to you the second you saw it. Then you, because you'd used up half your time on The Lamp, you didn't have much time for the others. When you were doing the Lamp, you were building a rather complex mechanism at the rear...
P2: But it was because when I saw the puzzle for The Lift, I knew exactly how to do it from the second I saw it, so that's why I moved on to The Lamp.
P2: But you started with The Lamp, and you ended up…
P2: I started with The Lamp cos I knew I wouldn't get the one with the train (The Scarecrow) and I knew I'd get the elevator and therefore I...
RESEARCHER: I have marked down, from watching the video, after 18 minutes you basically knew what to do with The Lamp for solving it, but you spent another 10 minutes trying to get it working, then you went on to The Lift. So, you did articulate what the solution was. I didn't go "yes, you're right!"
P2: I was a confusion of not, of forgetting I could actually remove parts. Cos I knew it was the bendy-ness of the K'Nex thing that did it. It was me forgetting, oh you could remove that. After 18 minutes of not knowing straight away.

RESEARCHER: It was interesting with The Scarecrow, that you, only a few people did that, pulling the string up and down to see how it worked. Why was that better than just visualising it?
P2: The pulling of the train? It's something you can't visualise, really.
RESEARCHER: You could give it a go. Most people choose to just stare at it and try to work it out in their head. It was obvious to you that that was better?
P2: It's nice to get a feel of what you can. Pulling it would have also seen how sturdy it was, or something along those lines. It's just the thought of being able to get a hint as well.

10. How did you feel about dealing with physical puzzles in a learning environment?
P2: Like I previously said, it's great to get hands-on into something first. Are you saying this from a beginner learning point?
RESEARCHER: No, just you, how you feel.
P2: A learning environment?
RESEARCHER: You've come to college, and the idea of physical puzzles that are meant to teach you something, how do you feel about that?
P2: I think it's a very good idea.
RESEARCHER: Or you could hate it, it's your opinion is what I want.
P2: No because, assignments are something which is repeated, while puzzles are something which leads to mistakes. You could do an assignment and get an A1. If you do a puzzle, there's a 99.9% chance you're gonna make a mistake at some stage. Like I said earlier, making mistakes are better than succeeding, sometimes. That's kinda my attitude.

11. How did you feel about your performance with the puzzles?
P2: Disastrous!
RESEARCHER: Really?
P2: Well, yes.
RESEARCHER: You solved one. A lot of people haven't solved The Lift, and you were easily the fastest at it. Several people knew what to do quickly enough, but it took them awhile to get it right.
P2: But they've made a song out of "Two out of Three ain't Bad", they haven't wrote a song about "One out of Three ain't Bad".
RESEARCHER: Combining that with your own attitude about the clues, thinking of them as lives that are lost, you've already said that making mistakes is better. So would you would have liked to have made mistakes, but still solved all 3?
P2: That's the happy medium, isn't it?

12. What would you have done differently?
P2: I would have really comprehended the instructions that were given, better.
RESEARCHER: You're thinking about The Lamp? Because you were very close.
P2: It's just a matter, when you're in that situation, after 18 minutes trying to figure out something, you'll always have that gap of knowledge which gets taken away in those 18 minutes or "I forgot you could do this, I forgot you could do that". Because of that went on for so long, it just led to complete and utter frustration taking over and comprehend anything is out the window.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P2: It would have affected your results a lot.
REPEATS QUESTION
P2: My thinking, I would have said…amm...
P2: The ability that you can choose how you're going to go about this, stay with one, with no hints...
P2: First of all, it stops any blockades, it allows immense freedom, and if it allows immense freedom, then that relieves stress and allows the thinking process to proceed, while if having, when you're always doing one puzzle, even though you know you're not acting on any other puzzle, you may be still thinking about that other puzzle, which the 1st puzzle can help you get the 2nd one. But, if you don't solve that 1st one, then the information you're thinking about to get the 2nd one is no good to you.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P2: Again, it made you feel in control. I'm all about control, I wouldn't want to become a Dictator now. It all made the process much easier to do. It made the puzzles easier to do, such freedom. Mostly because having access to all 3 means less chance of failure. And less chance of failure is always good.

15. What was your favourite aspect of learning like this?
P2: Well, my favourite part was that the pieces were made out of K'Nex.
RESEARCHER: Why?
P2: Childhood nostalgia.

16. What was your least favourite aspect of learning like this?
P2: It was easily broken.
RESEARCHER: It's possible to break it...What did you not like?
P2: Least favourite would be the frustration aspect and knowing that, OK, if you don't get it, you can cheat, the option of cheating is not a good learning experience.
RESEARCHER: Really? Because you didn't have to. You definitely thought it was a negative thing that you could get clues?
P2: Absolutely.

17. Did you learn anything useful to you? What?
P2: What I found useful was that when you showed me afterwards, saying that these actually related to real-life problems that happened, were solved by these people who won Nobel Prizes, that was my most interesting part that would have been it. Knowing that I solved a puzzle, like come on I'm 22 years and you're in your 40s. It's the achievement of it.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P2: Interesting...was also finding out...hard one to answer.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?

P2: It's always thinking about trying to think outside the box, that familiar phrase that we all hear about. Every week.
RESEARCHER: I could explain problem reframing in a lecture, but you did it. Do you think that helped you, or not?
P2: It helped, because when it comes to problems like these, it always means you have to think about past experiences. I have to think about what has already happened in your life that can be put to use here. Because if it's a learning experience, you need to learn so there's nothing which will be taught to you in the future will help you now. That experience that would have helped my outcome if I was a few years older. That can help you now. That would have helped the outcome of my results.

20. Do you care?
P2: Yes. Every day's a school day.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P2: It only helped me understand because I was so far away from the problem. Looking at it, from the elevator thing, I could see the elevator, I could see the whole structure of the elevator and the car outside and everything like that. Back then, when it was invented, people couldn't see things from that perspective. So I think that, being able to see the exterior from such a distance helped a lot in the problem. If I was in the building looking at the elevator, and only being able to see the doors of the elevator, and thinking "how will I do this?" that would increase the difficulty level, being able not to see outside the box, outside the building per se. I do believe having that perspective did help.

C3.3 P3 Transcript

P3: Single: DMD 4th Year

1. How long have you been studying design?
P3: 4 years. Well, does a year of MMPT [Multimedia & Performance Technology] count?
RESEARCHER: Not really!
P3: 4 years then.

2. What do you think defines a successful student?
P3: Somebody who gets good grades, comes out with a good degree. Somebody who…
RESEARCHER: What if somebody is good at exams, but they can't really do the things that they're supposed to be able to do by the time they're finished their degree? Does that still make them good, successful?
P3: It would make them a good student. It wouldn't make them a good designer.

3. What do you think defines a successful instructor?
P3: Somebody who is able to, like, get their point across really easily and not have to explain things a million times. Yeah. Like…
RESEARCHER: I'm perfectly happy with uncomfortable silences…
P3: No, but just like somebody who is able to get the point across properly, and get the

message across, the specific points and, like, so that you don't come out of the lecture or whatever it is, saying "what was that even about?" or "what do we actually have to do?", or something like that, you know.

4. Why did you volunteer for this testing with me?
P3: Cos you asked me.

5. How do you think the physical nature of the puzzles affected your reasoning?
P3: It was probably easier, because it's like 3D in front of you, as opposed to just having to almost visualise it in your head. It's easier to like pick something up then just think about picking something up, if that makes sense. And it was also just more fun.
RESEARCHER: Why?
P3: Cos it's less like...it's just like you're sitting down to play with Lego. It's not like you're doing an exercise.
RESEARCHER: It's K'Nex, stop calling it Lego.
P3: Yeah, whichever...
RESEARCHER: You were quite expert. The little training thing we did beforehand; you weren't even looking at your hands when you were doing it.
P3: K'Nex is really good, ok? But, I just found that it was, j'know when you have a 4-hour lecture, they break it up, it's like that what you do, to take your mind off things, j'know?

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P3: It's probably more frustrating than if I was trying to figure it out on a whiteboard, or on pen and paper or whatever, maybe because I wouldn't have really done that kind of thing before. Whereas I'm used to not getting things done on pen and paper. I've experienced that before, whereas not, in a set-up where you're essentially just playing, it's weird to not being able to do it, if that makes sense?
RESEARCHER: It wasn't just playtime. They were puzzles. And they were difficult.
P3: Yeah, but it still probably, I still, I probably found it a lot more frustrating, than if I to just do it on pen and paper, or on a screen or something.

7. How did "Working Alone" affect your thinking?
P3: If I was with somebody else, I probably, it would have been..., I think it would have been easier because I could have bounced ideas off someone, and if someone had said something it might have triggered for me so it probably would have been easier, but I didn't mind working alone. I quite like working alone, so it doesn't bother me either way. But, I do think it would have been a little bit easier if there was two people.

8. How did "Working Alone" affect how you felt?
P3: If I had, if there had been 2 or 3 of us doing it then, it would be like, if the 3 of us didn't get it, well it was 3 of our faults, not just my fault, whereas if it's my fault, it's just me yeah. Yeah.

9. Would you have preferred "Working in Pairs"? Why?
P3: Well now that I know the answers, I wouldn't mind doing it again myself. Amm, I think if, say it 45 minutes wasn't it? If it had been an hour on my own, I would have

preferred working on my own, but for the 45 minutes...yeah, pairs probably would have been easier.
RESEARCHER: It wasn't meant to be easy, and partially the time was picked...it did match up with lecture time. Also, they're times that are not impossible to do, but only 2 people out of 31 managed all three, so it was meant to force you into choosing what way to do things, as opposed to having 4 hours.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You didn't complete all of them, but…
P3: Any of them.
RESEARCHER: This is going from you saying things out loud. You had The Lamp solved, you worked out what to do. You had The Lift worked out, and you had The Scarecrow. So, you looked at all 3 clues for the Lamp, but I have down here, you said what to do before you looked at the 3rd clue. Once you'd seen the 2nd one, you said out loud what you had to do, and then you started changing your mind. I remember you doing it, but when I looked at the video, I can hear you doing it. Then you moved on to The Lift, you accessed all 3 clues and then actually you said the solution out loud.
P3: Did I?
RESEARCHER: Yeah. You stopped after a minute and felt you were completely stuck. So after about 2 minutes of starting The Lift, you were off it and onto The Scarecrow, and you said what the solution was, and then you looked at the 1st clue. And then you went back to The Lamp and then you ran out of time. It was odd in the sense that you said what the solutions were out loud. Maybe if you'd been in a pair, the other person would have acted on your solution. What happened with several of the pairs, people said the solution and other person wasn't listening and said something else which turned out to be not correct. So, yeah, so that's, I was chewing my own fingernails cos you had all 3 solved.
P3: It's frustrating, yeah...
RESEARCHER: You did the hard bit. The hard bit was working out how to solve them.
P3: I couldn't actually move them or figure out which way to actually stop what I had to stop or make whatever move.
RESEARCHER: Anyway, without having flashbacks...

10. How did you feel about dealing with physical puzzles in a learning environment?
P3: I think it was really good.
RESEARCHER: Everyone would say that, though. Why?
P3: Because it forces you to actually think whereas you could sit in a lecture hall and not take anything in. Even if you're in a Lab, and you have to do whatever you're doing, you can do that without actually thinking. It's the same as watching TV, you can watch TV but not actually be thinking. It's that same thing, but you actually doing something, you actually have to think about it. So that gets your brain going in a different way.
RESEARCHER: The physicality of it meant you can pick things up, and break them.

11. How did you feel about your performance with the puzzles?
RESEARCHER: Considering how well you did. Very few people, only 2 solved all 3, but very few people managed all 3, in the sense if they solved one, they might have the thinking right for another one, and not have the thinking for the 3rd one at all. You

managed all 3. If fact, you were the only person to manage all 3 and not solve any of them.
P3: It's very frustrating, because I felt like, from what I remember, I feel like I understood what I needed to do, but I just couldn't figure out the last link of it to make it work which was frustrating, and then when I was running out of time, I got a bit panicked that I was running out of time, because I spent, I can't remember, I think I spent a lot of time with the first one, and then eventually "oh no, I have to move on".
RESEARCHER: You were doing OK. You spent about half your time on The Lamp, and then you moved on to The Lift.
P3: Because I think my initial reasoning was, I'll do one, finish this one, then move on to the next one, finish that one. That kind of way. But, that didn't really work [laughs]. So, that was frustrating. But, I think when I started realising that time was running out, I was "oh no, I need to finish it quickly" and I get a little flustered then. I definitely think if I had another 15-20 minutes, I might have figured the last bits of them out. Yeah, it was fine...
RESEARCHER: You're reliving it now. Do you ever get flustered like that at the end of a lecture?
P3: No.
RESEARCHER: Why not?
P3: They're different.

12. What would you have done differently?
P3: I probably would have checked the clues straight away. Just to have them and get going faster. I think I would have tried each of them for 5 minutes each and then figured out which one I could probably figure out, like the one with the (points at The Scarecrow), I think I probably would have figured that one out, had I spent longer on it.
RESEARCHER: The Scarecrow one?
P3: Yeah. Because, the other two, I feel like I understood what needed to happen, but I couldn't figure out how to do it, whereas with The Scarecrow I knew it, literally, I had to try it this way or try it that way.
RESEARCHER: You have 7 minutes left when you even started it.
P3: With that one, I feel I understood it the quickest, but I didn't leave myself enough time with it. I forget the question...
REPEATS QUESTION
P3: I would've definitely spent 5 minutes with each, and then been like "whichever one is the easiest, get that one done."

13. How did the choice element, the ability to direct your learning, affect your thinking?
P3: I definitely had more freedom. I felt like the more I was going around and doing bits of all three of them, the more I was figuring out bits of the next one, if that makes sense? So, I think if you were just stuck on one, I feel like you could very easily get into "oh well, I can't do this now" or "I don't know how to move forward with this one", whereas if you move onto the next one, you can take your mind off it for a second, and think about something in a different way and it will trigger something about this one over here. And I liked the fact that you could choose to look at the clues or not. I think the choice element is good.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P3: I didn't want to open the clues, just cos I'm really stubborn, and...
RESEARCHER: Why is opening the clues bad? That's not unusual...
P3: It's kind of like cheating. I know it's not, but that's how I feel about it. It's like "Here's a clue!" I kind of felt like it was cheating a little bit. I know it's not, cos you're allowed to, but that's just how I felt about it, j'know?
RESEARCHER: It was like giving in, or just cheating?
P3: No, not even "giving in". It was "I should be able to do this! I've done 4 years of design. I should be able to do this!" And I also think that, because they're in little boxes, as opposed to maybe sheets that were turned upside down, you had to open, it was like you were looking inside a secret box. More like cheating. I don't know what other word to use.
RESEARCHER: Were you just looking at the clues when you were stuck. When you were saying what you would have done different, you might have...
P3: Looking back now, just "get over yourself", open them, look at them, it's grand!
RESEARCHER: You were preferred to open them up and solve them, then doing it...because you did do it your own way. You decided how to do it.
P3: Yeah, I think knowing how quickly the 45 minutes went, cos at first I was thinking "45 minutes is a long time", actually it's not. So, going back, I would look at them just because you are under time pressure. Whereas if you had 3 hours, grand, there's no need for clues at all, but because of the time, you know...

15. What was your favourite aspect of learning like this?

P3: I remember it now, 3 months later. I couldn't tell you about any of my lectures last month, or last semester. I probably could, but not as in depth, I couldn't tell you about how I'd felt about a specific one in November.
RESEARCHER: You could describe this, like you'd been in Vietnam, like in a war.

16. What was your least favourite aspect of learning like this?

P3: The least favourite aspect of doing it? I didn't like that I didn't finish it, but aside from that, like...that was pretty much it.
RESEARCHER: You were so close. That was so frustrating for me. Cos I thought, "you're going to do all three"
P3: Yeah, but I didn't...

17. Did you learn anything useful to you? What?

P3: I learnt how The Lamp worked. That was useful, if I ever need to build a lighthouse.

18. Did you learn anything that was interesting to you, and not just useful to know? What?

P3: I wish, 4 years ago, I started learning design like that. I think I would be a lot more confident in it and probably think differently and think better if we had been taught things like this, the whole way through. But that just makes me sad about my course, and not, like j'know...
RESEARCHER: These are given as examples when people are giving lectures mention, Mechanical Engineering courses will mention some of these things about how clever this is. OK, you didn't build the solutions but you did actually work out…
P3: What needed to happen, yeah.

RESEARCHER: It's the type of thing if you were a designer working on a problem like this and you were working with an engineer, it's the type of thing you're able to do it now, really well, and just get them to build the thing.
P3: Do this, please!

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P3: Yeah, because, at the end of the day, the solutions are actually quite simple. They're actually very simple. It's almost like you just need to step back for a minute and stop trying to figure things out, and just actually thing all you need to do is just move this down, put this here. It's actually really simple, it's not this big complicated thing even though there's probably hundreds of parts. It's not this complicated thing. It definitely helped.

20. Do you care?
P3: Yes?
RESEARCHER: Yes? How?
P3: I probably feel like I learned a bit more about design in that 45 minutes than I probably have done in most of my design modules, in terms of none of the rest of them have really changed the way I think about things, whereas with that, like if you were doing that for 12 weeks, or even 4 years, you definitely think differently, you'd come to the realisation that it's not actually that complicated, some things are really simple you just move one thing and everything works or whatever. So, in that aspect, it does make me care, cos I'm annoyed at my course.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P3: Yeah, completely...[long pause]
RESEARCHER: It's not that you have to give a philosophical answer, it's about you…[prompt] you partially answered this in the previous one, about reframing, where you learned to think differently...
P3: Yeah, I do think it helped, but I think that's more due to a lack of that being taught in the course. I shouldn't be learning these things now, in my final year. This should be 1st Year stuff.
RESEARCHER: What you think is what counts. You have had several modules where you have learned how to do things. You now know, how to do this know, or you know how to do that, but you think the instruction in how you should think was lacking?
P3: The thing is that, I'll finish in 6 weeks and have to look for a job. I genuinely, if I had to look for a design job, I would be so insecure going in to a design job, cos I haven't a clue. It's funny, because certain lecturers will say "You learned this in 2nd Year", but I don't remember it so I didn't learn it properly. You might think "I didn't do enough, I didn't study hard enough", but if the whole course is saying that, then it's probably not just me, it's probably the way we are being taught. We have this module at the minute with Nora and it's about trying to get a job afterwards, and on the 1st day, Nora asked us what did we want to do and we literally sat there with blank faces, "we don't know what we want to do!", because none of us...we were talking about how there's a few want to do a Marketing Masters now, because...a few of us were saying "we're in this situation, where over here we have design, and over here we have the marketing world. We're in the middle, and we don't have enough skills either way to push us one way or another. We're in this weird situation where we're not, we don't

have strong enough skills really, some people probably do, to confidently do into a design company and we also don't have enough of the marketing stuff, because we just don't, we didn't do much marketing. So…I've forgotten what the question really was, but you know so…
RESEARCHER: Keep going…
P3: In terms of design, it's so funny, because me and Niall went to Cristiano just after Christmas with all the work we had done for our FYP, and we were telling him how we got on with interviews and all these kind of things and Cristiano was "What?" We were "Oh, no we've done something wrong!" He was "I'm so sad to hear that you're only figuring certain things out now. You should've known this. This is what Design is. This is what Interaction Design is". We were "Oh, OK, cool" We didn't really know that." It's really sad cos we've spent, well I'm 5 years in college now but I have ...if I hadn't done things outside of college, I'd have nothing for a portfolio. And one thing as well is that, especially at the minute, one of our assignments is we have to do a portfolio, and on your portfolio has to be projects. Everyone was saying to Nora that "all the projects we did through college, we just did these to just pass, to get through college, we didn't anticipate that these are going to be the projects that might get us a job." I think the course doesn't really...I think as well that the course changed. Isn't it now called Interaction Design, it's not Digital Media Design? I think it was marketed wrong to us when we were in 6th Year. I came in thinking it was a media course, not a design course. And yes, ok it's in the title, but when I went through the modules at the time, most of the modules are different now and they changed along the way...yeah.

C3.4 P4 Transcript

P4: Single: DMD 1st Year

1. How long have you been studying design?
P4: Almost a year, I'm still in 1st Year. Since September 2017, I don't know him when it is, it's March 2018, that's what, like 7 months? 7 months.

2. What do you think defines a successful student?
P4: One who engages in everything, so somebody who is well liked, well known, who does well in exams, who is in Clubs and Societies, basically is in every part of college life.
RESEARCHER: Is that you?
P4: Yeah.

3. What do you think defines a successful instructor?
P4: When he communicates well, if I walk out of the lecture having actually learned something and can tell somebody else about it, then I feel like they've done a good job. If they haven't, if I walk out of the lecture either confused, or didn't really gain anything from the lecture, then I don't think the lecturer did a good job at all.

4. Why did you volunteer for this testing with me?
P4: I dunno, as a kid I used to do those little puzzle games, so I was like "puzzles? That sounds interesting, I'll give it a go". Turned out that I wasn't it good at them as I thought I was.
RESEARCHER: The word "puzzles" got you?

P4: Puzzles did, yeah, I like them a lot. I thought "that'll be fun, that's a bit different."

5. How do you think the physical nature of the puzzles affected your reasoning?
P4: Well, I'm very bad at visualizing things in my head, my spatial awareness and my mechanical reasoning are god-awful, so I feel like it would have made it easier, but then the other side of it is, I feel like in this particular case, cos it was literally changing the building of something, the actual structure, it would have been near impossible to do it in your head. If it was more like a brain teaser, it'd be more logical to do it on a board, if you get me. That's just my opinion.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P4: I got frustrated. I got frustrated cos it was like they were there fiddly, they were..., they looked complicated, even though the solutions were actually, looking back quite easy to, once you see them "oh that makes sense". So, I'm frustrated with myself to not get it. I think cos there was so many little pieces, I think I got frustrated with my own hands and everything.

7. How did "Working Alone" affect your thinking?
P4: See, I don't work well in teams. So, if I was, if it had been a pair, I would have actually got frustrated with the other person cos I would have realised I wouldn't be doing very well, and if they weren't literally dragging me along, that means they aren't doing well either and so then I'm just getting frustrated with them, blaming them.

REPEATS QUESTION
P4: Amm, it was more like I was more determined to get it cos it would be my issue when I did that. But, in the end, that didn't happen.

8. How did "Working Alone" affect how you felt?
P4: The fact that I actually didn't succeed, objectively, it was like I couldn't blame anyone else, it was entirely me. So, I ended up more, I actually did end up getting frustrated with myself but it was more a case of "oh well, that's at least, I know that like...there was no else, no other factors that influenced me, so..."
RESEARCHER: It was deliberate on my part, making them hard. Only 2 out of 31 people solved all 3. It was meant to be that. Now I think if it had been an hour long, I might have had a bigger amount. Several were minutes away...

9. Would you have preferred "Working in Pairs"? Why?
P4: On my own.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You started with The Lamp, immediately went into disassembling it, you were chatting away about other stuff while you were fiddling with it, you got the Lamp to switch on at 9 minutes, looked at one of the clues, then you knew how the switch worked, then you decided to move to The Lift, tried adjusting the slope of the track, which would be what a machine would do, logic, but at 17 minutes, which would be less than 6 minutes after starting, you said the solution out loud, you're saying what to do, but then you start using the thicker pieces and it's not possible with them, because I have it engineered so that if you use the thicker pieces, they push against the elevator,

and the elevator starts colliding against the walls and it gets stuck. If you loosen the supports for the elevator, or tighten them, sorry, it then doesn't have enough acceleration to get out of the car's way, and the car ends up running over it and trapping it into position, so that's not possible. So, you were correct in a few minutes, but you never recovered from using the thicker pieces. And then you went on to The Scarecrow. You were watching it. It was interesting you were asking me which was the easiest one to solve. Not everyone did that, but it came out in the interviews that people may have preferred that. When accessing the 1st clue about The Lift, you were saying "it's shameful" and then when accessing The Scarecrow one with 4 minutes left, you said "there's no shame anymore, at this point".
RESEARCHER: I've got marked down at the end if a puzzle wasn't solved, was their thinking correct? I have you down for The Scarecrow & The Lift "Yes". At 17 minutes, you had figured out what to do, you just got stuck. Before you looked at the 2nd & 3rd clue, you said out loud what to do, but then you had very little time left. You made a reference to "Professor Lacium?"
P4: "Professor Layton".
RESEARCHER: Layton! Sorry. I couldn't quite work you what you said.
P4: L-A-Y-T-O-N. They were like Nintendo.
RESEARCHER: (after Googling): Ah, I see it. It's, well, we'll discuss this later on, this is meant to be about problem reframing…For all of these [points to puzzles], you have to reframe them to solve them, as opposed to me just telling you what it is. For example, with The Slow Lift, you said about adjusting the track, which isn't reframing, it's just logic to make the car slower. But then you did reframe it. You worked about the triggering mechanism, and you did it for The Scarecrow as well. Its evil twin is Fixation, when the designer themselves introduces a constraint that it turns out wasn't necessary, so sometimes they're there, the people who give you the initial problem, who are paying for you, they say "this is the problem" and you say "that's not really the problem" and you remove it. Whereas fixation is when designers do it themselves. They put in something that turns out to be a terrible idea. Now if they put in something that's the correct idea, they've solved the problem. So, you were doing that with the thicker pieces and then you didn't realise that was a problem. Whereas if you had accidently picked up a thinner piece, you might have solved The Lift in a minute or two. So, it was to give you experience of doing them, rather than me telling. That was the idea.

10. How did you feel about dealing with physical puzzles in a learning environment?
P4: It's definitely more interactive, I would say that I remember...if I was asked to do them again, I'd be able to do them I'd remember, my retention was better. I don't know, it was so much more frustrating, I got so frustrated...I did like them, it was a different style, it didn't feel like a lecture, it didn't feel like a learning environment.

11. How did you feel about your performance with the puzzles?
P4: Lacklustre!
RESEARCHER: See, you were a hair away from solving 2, which was not that common. A lot of people solved 1, but they were stuck with that and didn't get the thinking for the other 2 at all. Only 2 people solved all three, and only a few got 2. You done the hard part for two of them and didn't quite make it, so it wasn't that bad.
P4: I dunno, I'm a perfectionist, so not getting, not quite getting there with either of them…

RESEARCHER: It took away from the experience?
P4: It was almost like it was a failure.
RESEARCHER: Fair enough. I tried to gauge it so it would be, not impossible, but difficult. As it turned out, I think I got it right, because only 2/31, oddly enough the 1st person to try solved all 3, so I thought I'd made a mess. If everyone can do all 3, that would mess up my thinking, but it was OK.

12. What would you have done differently?
P4: I spent too long in the elevator.
RESEARCHER: OK, the timing?
P4: I didn't spend enough time, I felt like I should have spent more time on the light bulb [Dalén Lamp], because objectively that was the easiest one. It was 1 piece. If I had understood...if I had taken the time I used in the elevator, if I had taken the time to understand the light bulb, I would have gotten it. So, more time on the light bulb, and less time in the elevator. I don't think I would have gotten the Scarecrow fully done either way, that would be it. Time management.

13. How did the choice element, the ability to direct your learning, affect your thinking?
RESEARCHER: Keeping in mind that you asked me which was the easiest to solve, and I didn't tell you…
P4: I started with the easiest one. Well, I started with the light bulb...
RESEARCHER: You started with, statistically, the hardest one!
P4: The light bulb?
RESEARCHER: By far the hardest.
P4: Oh, I thought it was the easiest one. I think it was the smallest, I kind of assumed it was the easiest.
RESEARCHER: A lot of people stared with it for the same reason. It's very hard.
P4: Wait, what was the question?
RESEARCHER: The element of choice, how did it affect your thinking. I just reminded you that you did actually want to know which one was the easiest.
P4: I wanted.
RESEARCHER: What would you have done with that information? What if I had told you the Lift was the easiest?
P4: I would have started with The Lift so that I could finish it, so I could leave me on a high to go on to the next one. I went with the Light Bulb [Dalén Lamp]. I feel like the choice was not to use the hints at the start was because I was cocky, I know I was. I was cocky, it'll be grand, I can do this. Then towards the end, I was humbled, and I remember thinking "all 3 have used them, it's OK". There was an element of desperation involved.

14. How did the choice element, the ability to direct your learning, affect how you felt?
RESEARCHER: How did it make you feel that you had a choice? Would you have preferred I listed them in order of difficulty? I didn't give you that choice, because I didn't tell you.
P4: Actually no, I don't think so, cos then I know I would have tried with The Lift first, and if I hadn't gotten The Lift first, I would have given up.

RESEARCHER: Interesting. The element of choice in real life, if you go into town to get a pair of shoes, you have to get the right size, and you do have a money budget, but after that it's your business what to get. Whereas in education, you often told how it has to be. The element of choice is seen as important, but actually putting it in to an educational program is difficult. So, that's what I've been looking at. A couple of people specified they would have liked more guidance, because they were more concerned with solving them, whereas I was wondering if it made a difference to their experience, but I was wondering make a difference to people. You did ask. That was interesting.

15. What was your favourite aspect of learning like this?
P4: Almost a sense, it sounds ridiculous, almost a sense of an adrenaline rush, of using my brain in a different way, I spend a lot of time in lectures, actually been given problems to solve, I have to rack my brains, it was different, a kind of fun, a different style and I kinda liked it.

16. What was your least favourite aspect of learning like this?
P4: The difficulty. I would have preferred if there had been, the hints, I didn't like the help, it was like the hints weren't helping me. The hints were kinda like the lowest rung of hints, basically I'd get a literal piece of the puzzle and I would have no clue of what to do with it.
RESEARCHER: Part of the reason they didn't help you that much was because your thinking was correct. They were meant to correct your thinking if you were going down the wrong path. You were doing fine with that part. It was just the last step; they weren't really helping with that.

17. Did you learn anything useful to you? What?
P4: I learned quite a bit about myself, actually. I learned that I don't like being wrong, at all...I probably should have known that already. I also over-evaluate myself, it was very interesting to see the...how I...almost, I could tell myself whether or not I was going to get it, so I could drop it if I didn't like the way it I was going, if I couldn't format it, I wasn't going to deal with it, move on, just drop and go. About myself, it was interesting to see, looking back, how I handled myself.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P4: Interesting? How much I enjoyed it actually.
RESEARCHER: Despite your rage?
P4: That's the thing. In the end, at the time being beaten by the puzzles was annoying but it was enjoyable, it was fun, almost being beaten by pieces of plastic...I was very interested how I enjoyed it, you are human, you are not a god, you can calm down, it was very interesting.
RESEARCHER: Fixation isn't an amateur problem, it tends to become more of a problem as someone becomes more expert, they have more confidence in their opinions, and it takes an amount of skill to try something, and if it's not working let it go, instead of insisting it has to be part of the solution. It's something experts tend to do. It was certainly what did you for The Lift, because you immediately worked out what to do, you had a couple of goes, once you got over the logic part, you went "oh no, I have it!", you had it, but it was because you started with thicker pieces. Everything you did with the thicker pieces was perfect. If you had switched to the narrower ones,

you would have been fine. Because it was just in your head...In principle, what you were correct, you were right to be confident with that. It was just that the thicker pieces were too strong and were inferring. If you had confidence in your principle that was behind it, which was correct, but not emotionally attached in any way to the shape of the K'Nex pieces, it would have been easier for you to try something else, without adjusting your idea. But, that's a skill that has to be learned. It's like, when you're beginning it's difficult to learn it, in the middle, you're OK. Then there's a danger when you're an expert because you're more confident.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing? (and its evil twin, "fixation")
P4: Definitely, fixation was a big problem of mine. Reframing? I know I reframed The Lift, because I did try originally, understanding, thinking outside the box worked, but when I did think outside the box, it didn't work. That's my understanding of reframing and fixation.

20. Do you care?
P4: I care that I learned that I need to, I know that fixation is something I do in everyday life, so it's almost having to acknowledge it, it is seeping into my education as well. Makes me realise I might have to deal with it.
RESEARCHER: It's early days.
P4: Yeah, definitely.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P4: Learn how to think? Yeah. I would say it actually did, yeah, we had a talk, last...yesterday, by..., it was so early in the morning I can't remember, some guy was a designer, and he had this whole, he was reframing everything when it came to design, and that's something I'd be very interested in doing, but it made me realise that, for that to happen, I'd have it get better at reframing, so I'm hoping...

C3.5 P5 Transcript

P5: Single: DMD 4th Year

1. How long have you been studying design?
P5: So, 4 years? Almost 4 years in May. I'm in my 4th year.

2. What do you think defines a successful student?
P5: I thought about this one, when I read the questions and I was thinking about it. I think it's the student who is the most dedicated, the one who does all the assignments, goes to all the classes, you don't have to be brilliant at Maths. A student could be bad at maths, and if they show up to all the classes and do all the assignments, and they get a B, it's not an A, it's a B, that's successful to them, so I think it's the ones that are the most motivated and to get what they wanted out of it at the end.
RESEARCHER: You talking about yourself there?
P5: No...

3. What do you think defines a successful instructor?

P5: Yeah, I think it would have to be, if I think about who has taught me, the ones that I came out, feeling that I could do the assignment without having to research for a week on certain other things. They give you what you need and then you can go and do it. I think that's a good instructor. I've have assignments where they touch on a part of it in some lecture, and it's really vague and then they say "go and do this" and I spend the first half of my time looking up how to I do this, this and this. I think the ones that give you everything you need to do the task that you have to do at the end, either an exam or assignments, yeah they're the most successful. I probably do the best in their stuff, you know exactly what they want, their thinking of it as well.

4. Why did you volunteer for this testing with me?

P5: Because you're nice! I'll help you out. That's all. Literally...

5. How do you think the physical nature of the puzzles affected your reasoning?

P5: The physical, I think, it's very like "a picture speaks a 1000 words". I would say it's very overwhelming, that's one thing I would say, I don't know if it's because the 3 of them are together in the same space and you're like "where do I look, where do I start, what's what", but, I dunno, I kind of liked it, that you could play around with things, take things apart. I liked it more it more than being given a sheet and told "you have to do this; you have to do this". It's very visual and...it's more logical to think about it when it's in front of you, you can play around with it in your hands. I think it was good. Very interesting.

RESEARCHER: When you were actually doing the puzzles, do you think it made a difference that is was physical, the way you were able to think?

P5: Yeah, because you could pick it part, with The Lamp one, you could take apart things first and see that, "ok that doesn't work, put it back together, try something else". You could also see The Elevator, the key to that was seeing how, where the problem, well what I was thinking whereabouts was it was letting off the taxi at the top, so seeing that brought the answer straight away, whereas if it was on paper, you would be like "where is it! I don't understand", so I think it was way easier to see it while you were doing it and playing around with it and what doesn't work, doesn't work and you know that. You can go along, it's like code, when you so much and you think you're going good, and it's like "NO!".

RESEARCHER: "That's not working"

P5: Then you go back...

6. How do you think the physical nature of the puzzles affected your emotional engagement?

P5: I would say overwhelming. When I came in first, I was "that looks so hard, I don't anything about K'Nex!", and they're all laid out together, and you're like "where do I start, what's what! and it's scary and so tall" At the start you're a bit kinda like, oh wow, this is gonna be way too hard for me to do. But it's only when you get into it, it's "ok, I can do this. I can do this." I think initially, the emotional side of things, that's way out of my league, that looks so big...but other than that, it's fine, once you get into it and you know what you're doing, they're no emotional effect. No bad emotional effect.

RESEARCHER: Once you got started, you were happy?

P5: Yeah.

7. How did "Working Alone" affect your thinking?

P5: I feel like, you probably know this from the video, I think in my head, so I'm just very quiet, and I might be staring at something, but my head is going at a hundred miles an hour, so I feel like if there was some else there, I'd literally be like [pulls serious face] and "they'll think I'm dumb", but really I'm processing it myself. I think that's how I work, so that's how I think myself. I wouldn't be someone to say "I might put these keys over here" out loud. I'm just in my head and I'd have a hundred thoughts and I don't say them when I'm stuck in a problem.

RESEARCHER: If you're forced to say them, would that be a problem for you?

P5: If I'm forced to say my thoughts no, but I try to take a minute to think about which one sees the most reasonable, or could be the right thing. I might have 5 different thoughts in my head, I could do this, this, this or this, and if someone said "what are you thinking?" I'd be thinking "which one is the closest one?", thinking we might do this. So I think working alone was better, for me anyway, because I wouldn't have that awkwardness with someone where I'm quietly thinking away.

8. How did "Working Alone" affect how you felt?

RESEARCHER: It was more comfortable for you?

P5: Yeah, I would say it's more, not more comfortable because I would work with someone as well, but it was a different way of going about it almost, amm...I think maybe… I think the outcome would be,...ok, if there was someone else there, I think that I'd be kinda like if they had a solution, I'd forget about what I was thinking and go along with them, cos I'm kinda like "you're better than me, that's great, work away", whereas when I'm left to do it myself, you feel more responsible or something, like this is all on you, so everything you do will either work or not work, so it's a bit more pressure maybe, but the outcome is...I won't say I would have done better myself, but I could've not got lost. I might have got lost if there was someone else there as well, if there was too many ideas going around, and I'd be more like leaning towards them, "you're so right", that's just how I am. "No, we won't do what I'm thinking, yours is definitely way better!"

9. Would you have preferred "Working in Pairs"? Why?

P5: Yeah, I think I suppose I didn't know what I was coming into to do either, so I'll do this myself in case it's so hard and I look so stupid. But, I think if I knew what I was doing originally, well I had some idea, I didn't know any of the puzzles or anything.

RESEARCHER: That's the whole point, otherwise...

P5: Yeah...I think for this project specifically, it would be good to work in teams or pairs because it's physical, you can mess around with it so much and you can put it back together. I think there's projects where we're working in pairs, it gets way too complicated, like for a report or something, something like that I'm "no way, I want to do it myself". I hate when lecturers are like "you can do the report, but break it up into 4 people" and I'm like "no, let me do the whole thing!" but something like that would be fun to do it in a pair, but I didn't mind working on my own, it was fun at the same time. I'd nearly have to do it as a pair to compare it, you know.

[REFERRING TO VIDEO NOTES]

RESEARCHER: You started off with The Scarecrow, and straight away didn't like the look of it…

P5: Yeah! I went to the smaller looking one...

RESEARCHER: You went to The Lamp...
P5: Yeah, that ties into what I said about the physical nature of the thing, it was so "whoa, I've started off with a really big one and it's so tall and looks so complex".
RESEARCHER: You skipped, but stayed with the Lamp until you solved it.
P5: This looks small; this is less intimidating.
RESEARCHER: You looked at 2 of the clues. But, then solved it, so there was no need to look at any more. Then you went to The Lift and looked at 1 of the clues, but you did solve that one too. Then with 3 minutes left, you went to The Scarecrow and you opened the clues immediately, cos you'd already looked at it in the beginning and worked out what to do. Talk to me about that…
P5: So, as I was saying I started off here [referring to The Scarecrow] cos this was the first one to me, and I was like "No", cos you need to ease into those things, cos when you're given a big problem, you're like "argghhh!" I went for the less intimidating one, I was "No, I won't start with that". I got that one [The Lamp], and I knew that I'd struggled with this [Scarecrow], so I was ok, I'll do something different again, I won't go back to that.
RESEARCHER: You went to The Lift instead of going back to The Scarecrow.
P5: Because I know what it was and I knew I didn't have a solution yet, or even a direction and I went to The Lift. Then, by the time I got to The Lift, I knew I was under time pressure, OK, my main goal was to solve all of them, so I'm gonna use these [clues] if it means I'm gonna solve it quicker. So that's why I jumped to the clues and because as well, I still had no idea, I kinda thought as I went along, I'll be like "ahh, this breaks off, or this is bendy" but I still didn't have a clue about that one, no, I'm gonna jump to the clues, there's no point in me wasting time.

10. How did you feel about dealing with physical puzzles in a learning environment?
P5: Yeah, I thought that was really cool, you just got more of a satisfactory feeling when it's finished and completed in front of you. I think when you see the outcome of something you more like "yeah, motivated". I remember texting my Dad "you would have loved that", cos he's so...that's so up his alley, puzzles and stuff. I was like "yeah, this one, it was really hard". I was more excited about it that you come in at the start, and you actually get through it at the end and you're like "oh look it works!" It's more satisfactory and motivating and exciting.

11. How did you feel about your performance with the puzzles?
RESEARCHER: You solved 2 of them, which was above average. 1 1/2 can't be done, it was better than average, and you did work out how to do The Scarecrow so if you'd had another 5 minutes, you would've solved all 3.
P5: I think, "the performance", I should have stuck with my gut and started with the one that looked less intimidating, cos I thought that when I came in, I was "that thing over there [The Lamp] looks less scary", I should've not wasted time looking at this first [The Scarecrow], I think I just done it because it looked like the logic choice, the first one. And I feel like if I didn't, oh The Lamp, I knocked the thing out of the place, and I was like wondering for ages "how does, why is it turning off if I do this, so how does it stick?" That caught me for a long time, so I think I would have figured out that I had it knocked out, I would have solved The Lamp quicker. Then, The Lift...did I use a clue for The Lift?
RESEARCHER: You did, you used the first one, you were annoyed it wasn't any use to you.

P5: No, not that! I knew I should've stuck with what I had in my head before I used the 1st clue. I knew the answer to that, but I was "No, I'm just not gonna waste time here now and go with what I think, I gonna use the 1st clue to see if I was on the right path. Not waste my time", so I was annoyed I used the clue cos I did know, I had a good idea of how to solve that.
RESEARCHER: Do you think using the clues was giving in, or less impressive?
P5: Yeah, not giving in, but less impressive. It's cooler when you come up with it yourself with no help but the last one [The Scarecrow] as well. I think was the last clue how you put the cardboard?
RESEARCHER: Yeah.
P5: I think I had the shape of the cardboard done, and I was trying to arrange it and then I was "time, time". Or no...did you show it to me at the end? I can't remember...
RESEARCHER: I showed you at the end, cos you didn't access that clue yet.

12. What would you have done differently?
P5: I was "Oh no!" I had it there, but I didn't get it down. There was a load of annoying things. If I done it again, I do it different, definitely not waste my time at the start. With The Lamp as well, I definitely know what I was doing, but didn't know...it's like I had the key, but didn't know where the hole was. I knew that I had to have something standing up to press it, but it was, I didn't know the last bar could be changed to a flexible thing. I was "arghh!" It was so easy but I knew what to do, but didn't know how to do it. It was frustrating, but it was fine. It was fine.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P5: I think it suited me to a tee, cos that's what I do anyway. I find if I'm given an assignment and it's 3 parts, I'm doing the 1st part and then I get an idea for the 3rd part and I'm like "skip down!" and I do this little bit, and put this over here, and then I have to go back. That's how I work anyway. If you told me "you have to do number 1, and you're not allowed go to number 2 until you've number 1 done", I think I would have been a bit frustrated. I think it would have got me down, instead of letting me be "this isn't the end of the world", I can try something else to refresh my head. I keep needing a refresh. It's the same with, if I was doing anything, even an essay, if I'm going out about something too long, it doesn't don't feel good to me anymore, like I don't feel like what I'm writing is any good. I'll look into the next bit, then write a little bit, then come back, so I'll re-read what I did about the old thing. OK, that wasn't too bad. I'll add in this, this, this. It's one of those things where if you look at something too long, you start to hate it.
RESEARCHER: What about the clues? How did that affect your thinking? That you knew they were there, but you didn't have to access them.
P5: I kinda wanted to do it without using them, just to see how far I would get, but because I doubt if what I'm doing is right, I'm like "maybe I should check" I think time, if I had all day to do that, I wouldn't have looked at any clues. I think time was catching me big time, cos I was "I need to move on" and that's what made me move from the puzzle at the start. I'll move on and come back. Refresh! I was annoyed that I kind of used the clues cos I feel I would have eventually done it, done all 3 without any clues, even if I made a 100 different mistakes, I would have figured it out, but...just. What I would say about is just time. It was easy to speed up time and see if you were going right. Not so much "I need the answer", but "is what I'm doing, am I wasting my time with what I'm doing? I'm just gonna check." They were nice to have, in terms of

thinking, they were like when you're on a diet and there's a chocolate bar over there, they're like that. I want to do it myself, but because of time, I probably should use this. It's a bit less exciting, less satisfactory at the end when "oh I've done it, but I used all the clues to help me out"

14. How did the choice element, the ability to direct your learning, affect how you felt?

P5: It suited me perfectly. I would have got totally frustrated if I wasn't allowed move on unless I got one done. I would have got too stuck down on it and probably would have went off in the wrong direction. I think the ability to roam around and see...there was some other things that I took from...The Lamp, that the bars come off, OK, I can take off a bar, the notion of taking things away came to me at this, or changing things, I was on a roll.

RESEARCHER: When you were doing The Lift.

P5: Yeah, it was just nicer to be free to be left at it and then solve all 3, whatever. No, if it was one-by-one, I wouldn't have even got the first one done. If those 2 [The Lamp & The Elevator] were blanked out and you couldn't see them and there was just 1 in front of you, and it's "you're not allowed go to the next one unless you do it!" I don't think I would've done it at all. I know that from even projects, I always say that "I'd love to have all the module assignments at the start so that I can do them. Instead of "here's your 1st one", and you know you have 3 to come in Week 7. That's just how I am. I loved the whole "you do what you like, you explore what you like, solve what you like" aspect.

15. What was your favourite aspect of learning like this?

P5: I don't know...I would say...is it the physical-ness or what? But you feel you've got something at the end, when you've solved it or even if you don't solve it but you're told how it was done, you're "I get it now". You've more of a "ohh, I understand", instead of in a lecture, you're reading off slides and you come out and say "what did he say at the start? I don't really know", whereas I knew, I was able to tell my Dad afterwards what everything was, what all the clues were, what way it was set up, what material were there even, so it's more memorable because it's more fun and engaging, whereas in a lecture you shut off and you miss 3 slides "wait, what did he say?" I think my favourite aspect was that I feel like I was more, I understood more, I understood the solution to all of them, I wasn't left confused or I didn't know the answer and it would wreck my head for the rest of the day. Yeah, it was more fun.

16. What was your least favourite aspect of learning like this?

P5: As a learning experience, or just the whole thing?

RESEARCHER: The whole thing.

P5: It's because of the way I am, but it would probably be what I said at the start, when I came in, it looked so "wow, I'm never going to be able to solve that", it's probably off-putting, I'm probably getting off on the wrong foot, instead of "this looks like something I can do, let's go, let's go!" This is so hard, my mind-set. Because it looks so complex, so big, that it made me start off on the wrong foot, but once I got going, with The Lamp, I was in the right mind[set], I was away with it...not that I disliked it, that's just me, I'm more like "that's scary. I'll never be able to do that" That's what I least liked about it, but literally just me, I think.

17. Did you learn anything useful to you? What?
P5: Knowing that if I didn't have the time constraint and I was left to them all day, I probably would have got them. If I had been like that at the start, had that...you know well could have done this, I would've solved everything in the time, without clues. So I think I've learned not to be put off. "This isn't bigger than you, you can actually do these things!"

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P5: When I looked at these questions, I remember specifically looking at the table and everything, and seeing a box in the middle with a collection of sticky notes whatever, I felt they all should have a purpose somewhere. I won't say it put me off, but I never went for them until the end, but I was never "do I need them?" But I was "mmm, they are there for a reason, so am I going off the beaten track for a little bit? That was interesting that you didn't need everything to solve it. Like, The Lift was changing one little thing, and the whole thing was solved. You have all these materials on the table and "I'm gonna have to build a big contraption!" The most interesting part was how 1 little thing could solve the whole lot. That was interesting to me.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P5: Yeah. Seeing it, like...The Lift, straight away, when I got to that, I was "why, what's letting off the taxi?" The problem was given that the taxi's too fast. I was "step back, what's letting off the taxi, how can I stop that?" Seeing it visual, right there, you can change things, you can mess around with things, gets you in the flow, this doesn't work, if I do this, this happens, if I take this, if I move this little thing, the whole thing is solved" I think it was really helpful, if that was wrote on a sheet of paper, I would be like "no, I can't solve it"

20. Do you care?
P5: Yeah, I always care! I'm someone who would take things on to learn because I care. I would say I care!

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P5: I think, like what I was saying to the other question, it's...the problem is there in front of you, and you have to go back and say "why is that a problem, what's happening now that's causing the problem?" It's easier to visualise it, to see it, afterwards, no matter problem it is, you should go back and "why is it happening?" It's way easier to understand the concepts of..., how you should go about thinking about things. I even know that from when I started off with this, I don't know where even to think, what to do with my head. Once I got into it, I was "wait, if this comes off, light goes off, whatever I was doing with The Lamp, this is going on, this is going off, that must mean I must do this" It's like dominos. It was really helpful.

C3.6 P6 Transcript

P6: Single: DMD Graduate

1. How long have you been studying design?
P6: 4 years.

2. What do you think defines a successful student?
P6: In a University sense, doing academically well. Not failing would be a successful student.
RESEARCHER: OK, but that's just the results. How does someone get into that position where they're not failing?
P6: Working hard, doing all your assignments, keeping on top of things.

3. What do you think defines a successful instructor?
P6: I think you have to someone confident, someone who knows what they're doing, I have a module right now with a girl, she's teaching and she's a PhD student and she hasn't a clue what she's doing. It doesn't motivate me to attend the class or anything like that. Someone's who's confident, who knows what they're doing, who has a passion for teaching that particular subject.

4. Why did you volunteer for this testing with me?
P6: Cos we're friends and, I don't know, it seems interesting, why not?

5. How do you think the physical nature of the puzzles affected your reasoning?
P6: I think, because, I knew there was 3 of them, and I could see 3 of them and I knew I was being timed, I to get all 3 done in as short a time as possible, and you can see them in a physical sense and you can try them over and over again.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P6: I think, cos they were physical, I wanted to have them, to see them complete and know that I'd done them fully, I suppose.

7. How did "Working Alone" affect your thinking?
P6: I think…I imagine that I would have been better working in pairs or in a group. I obviously solved the Batman one [The Smuggling Scarecrow] and kinda solved The Lift one, but I feel if I'd had someone else there to talk about it and they could see it as well, then more brain power working on the one thing would have solved it quicker.

8. How did "Working Alone" affect how you felt?
P6: I felt stressed, but I think I would have felt the same even if I'd been working in a pair. If we'd been working in a pair and still didn't get it, I still would've been just as stressed.
RESEARCHER: What if you had been working with Kim, someone you were comfortable with? Would that have felt more comfortable for you or what?
P6: Probably would have made me feel more comfortable with it because there would have been 2 of us, either 2 of us succeeding or 2 of us failing together.

9. Would you have preferred "Working in Pairs"? Why?
P6: Yeah, yeah.

[REFERRING TO VIDEO NOTES]
RESEARCHER: Why did you pick The Lamp?
P6: Cos it looked to be the least intimidating.
RESEARCHER: Why?
P6: Cos it's smaller and it wasn't at a height.
RESEARCHER: What you did was that you opened up the clues sequentially. After 2 minutes, after 4½ minutes, after 5½ minutes. Then, once you have the 3 clues open and you still weren't happy, you went straight onto The Scarecrow. You opened the 1st 2 clues, and then you solved it. Then, instead of going back to The Lamp, you went onto The Lift. You opened all the clues, then had a couple of problems and was flitting back between them. One of the things...you were so close to solving The Lift. [Researcher now produces part of the K'Nex Lift structure] This was the bottom of the structure. This is the thing you had to change. For the purpose of the tape, I am showing the suspect! This was just there; this was not necessary. You kept staring at it and doing this with it [touching the end piece of the K'Nex structure]. Touching it. If you had done that [snapped off the end piece, and attach a long narrow bar to end], then attached another one on, you would have solved it. It seems you got stuck because of the way I made the puzzle, because you saying things like "I don't want to break it".
P6: They're the same colour though, as well. It looked like this one thing. It looked like a uniform thing that you weren't meant to take it apart, so "I'm not going to take it apart!"
RESEARCHER: You seemed nervous. Every time I tried to hint at what you could do, you were "I don't want to break it!", and "it's so stressful!" You kept laughing, but in a stressed way the whole time. What that because of the time?
P6: The time, definitely. Yeah, even in a video games, when you get a time trial it's literally the most stressful thing I've ever experienced, it's so bad. If you said "come in for the day, have all day at it", I probably had been less stressed about it, but that would have made no sense to have all day to solve really easy things.
RESEARCHER: They weren't that easy.
P6: In retrospect, they were.

10. How did you feel about dealing with physical puzzles in a learning environment?
P6: I think it's a good idea, because...I wouldn't say that I'm very book-smart, I would say I enjoy learning with my hands, different ways of learning then sitting in class, looking at lectures, looking at slides, so I think it's a good way of teaching and learning.
RESEARCHER: Unlike swimming lessons, the whole point is that you should be able to physically do it by the end by the end of the lessons...it wasn't a K'Nex lesson. You were supposed to learn something philosophical. You were still happy with it?
P6: Yeah.

11. How did you feel about your performance with the puzzles?
P6: I feel like I could have done better, obviously. But, I'm pretty proud that I solved the Batman one [The Scarecrow].
RESEARCHER: Like that! [clicks fingers]
P6: Yeah, that was OK.

RESEARCHER: And very cleverly. It was the same thing in principal to the way I did it, but in reverse, but it still worked.
P6: I wish I had done the other ones, I would have felt way better and really smart in myself, and less disappointed in myself.

12. What would you have done differently?
P6: I probably would have calmed down, like "OK, it's not a big deal", I feel like when I was doing it, I would've looked at it as one big picture, rather than focusing on these things and I felt like I was getting overwhelmed then by focusing on this, and why can't I do this and that this isn't working. I don't know, I still feel like I was to do it again without any prior knowledge, I would've done the same again.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P6: I think because I knew I had the clues, I'll attempt it by myself for a minute and if I don't get it, I'll go to the clues immediately. They were kind of a backup. I was using them as a backup. Ok, I can't do it myself, I'll use the clues and it'll be fine. If the clues weren't there, I would have to solve them based on my own brain power. So, they were back up for me. But maybe bad, cos I didn't use my own...by myself. But then again, if I didn't have the clues I may not have solved any of them.
RESEARCHER: What about being able to move back and forth? Did that affect your thinking in any way?
P6: Move back and forth?
RESEARCHER: Without having to solve them first.
P6: I think so. I think it might have done me bad, because I was getting frustrated with one of them so I went back to the other, and that was just frustrating as well cos I couldn't do it. So, I went round to all of them. I don't think it was good for me, but that's just probably because of the type of person I am.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P6: The fact that I could was good cos I had options, I wasn't "OK, I need to get this done before I can even attempt the other ones". It's good as a whole, but I'm saying, me, I would prefer to have one thing completely done before I go to the other thing. But because I couldn't solve one of them, I was getting stressed, so then I was "ok, I'll solve this one!", but then couldn't do that either!

15. What was your favourite aspect of learning like this?
P6: How interactive it is, because I think once you do have it solved, you can see the results immediately, you can see straight away that you've solved it. It's rewarding to see it if you've done it correctly.

16. What was your least favourite aspect of learning like this?
P6: I know it seems like I hated it, and I kinda did, but I don't think there was anything I really disliked about it.
RESEARCHER: Why were you getting so stressed?
P6: Cos I couldn't do it. I wanted to solve them all, and I couldn't do it. The least favourite thing was how obvious it was, to solve.

17. Did you learn anything useful to you? What?
P6: No? I don't think so...I know you were relating it back to things that existed in the real world, but I don't know how valuable they are to me in a design sense. I think I learned a lot about myself. But in a design sense, no...sorry.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P6: I don't know...I don't think so...I can't think of anything.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P6: Like, doing it? Oh yeah, definitely. I think it goes back to being apply it immediately there and then and being able to see the results of it. I won't ever forget this. If you just gave me a set of rules to read and learn, I'd be "whatever". To me, it goes back to the way I learn things. I will never forget this, so...

20. Do you care?
P6: Yeah, I wouldn't say that I don't care. It was an interesting experience.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P6: Cos it's much different to having an instructor telling you what to do, because you have to do it yourself, so you are forced to come up with the solutions without being told how to do it. Independent thinking and stuff like that.
RESEARCHER: [referring to a piece of K'Nex] What happened to you is called Fixation, you come up with a good idea, it's the opposite of Reframing to an extent. Now that you have it in your head as a fact, everything you do is based on this "fact", even though it's not a fact. Because of this thing at the bottom, it was barring you from realising you could just make it longer. You were even saying the words "if I could make this longer", but it was like you couldn't break this off or the machine would fall apart. You got stuck on this. That wasn't meant to be what happened, but at least you learned it.
P6: Thanks Researcher.

C3.7 P7 Transcript

P7: Single: DMD 4th Year

1. How long have you been studying design?
P7: If you say "studying in formal sense, reading, looking at design", then since 1st year, 5 years now. Other than that, it was just looking at designs saying that's pretty, that's all. It was never really studying it when I was younger, so 5 years.

2. What do you think defines a successful student?
P7: The ability to showcase how to mix different elements together. So not necessarily the grade at the end of the day, but the ability to understand this element works well here, this element works well there, that same concept can be used across different places, being able to identify that this is something...

3. What do you think defines a successful instructor?

P7: I think it would be a situation where they're not so much telling you this is the way to do it, rather than this is a way to do it. It's more compartmentalised into different elements that do different things. So with Photoshop, they...I think would be successful from an instructor "this tool is this. There are different settings that affect this. They can be used in various different ways", but showing them that you can get the same or similar product at the end using different tools, but all of them being a different way to get to the same place.

RESEARCHER: Clarity, and the why you're doing it?

P7: Yeah, kind of understanding what makes up the entire whole, so it's like teaching a kid to remember 2+2=4, but also making sure that they know that 5-1=4 and 3+1=4 as well, the different ways to get there, but the basic idea of adding two numbers to make another number is what they're being taught.

4. Why did you volunteer for this testing with me?

P7: You found me in the corner and then cornered me.

RESEARCHER: Surprising common answer...

5. How do you think the physical nature of the puzzles affected your reasoning?

P7: It gave me a lot more opportunities to try different things. I wasn't necessarily limited by thinking how something should work. In ways of, when we think of a paper clip, when you tell an adult to think of the paper clip in their head, they'll think of one that is standard size that goes on the corner of the page. Tell a child to think a paper clip, they could think of a 1000 different versions of a paper clip, they could think of a foam one, a glass one, a giant one, a tiny one. As you get older it's just the way life goes, you decide to focus on one thing or another. The physical aspect took that away and you could see how things actually moved, you could see how things were actually put together instead of just assume that the pieces were working as they should, thinking in your head.

6. How do you think the physical nature of the puzzles affected your emotional engagement?

P7: More frustrated because even though I could sense where they...what they could do, where they would be able to go, I was frustrated that I couldn't magically change it in and out of my head, as quick as I could in Photoshop. That colour doesn't work, change it to another colour, change it to another colour. With the physical aspect I was more focused on changing the physical thing, then going back into my head and thinking about it and breaking it apart. I had a habit of breaking the 1st one a lot.

7. How did "Working Alone" affect your thinking?

P7: Not really quite sure. I talk aloud quite a bit anyways, and most of the time I do it even in a group. It just so happens that there is a person there that engages with it, so I don't think it really changed much. Working in a pair would have helped me develop ideas a little bit faster, but I don't think it was different to how I would have worked normally.

8. How did "Working Alone" affect how you felt?

P7: Didn't really. Just like a normal day!

9. Would you have preferred "Working in Pairs"? Why?

P7: Given, in its concept, I think it would be an interesting thing to do in a pair, like those Murder Mysteries. The same concept, you could try and do it on your own, but then you only have the satisfaction in yourself of knowing "oh, I got that right!" If you have a pair, it turns less into just a puzzle and more into a game, it brings a different element of enjoyment that may have been more relaxing.

[REFERRING TO VIDEO NOTES]

RESEARCHER: You started with The Lamp, and straight away, within seconds it was in your hands up in the air and you were twisting it around, as opposed to staring at it. Several people just stared at the things for a while. I had to reset The Lamp because it was possible to break it, but that was fine. You looked at, not at so many clues. Out of the 9 possible clues, you only looked at 3. I have referred to the fact that even though you didn't solve The Scarecrow, you did work out not only what to do, but how to do it, but you ran out of time.

10. How did you feel about dealing with physical puzzles in a learning environment?

P7: I think it's something that could go hand-in-hand, in terms there's a space, cos we do a lot of prototypes with paper or cardboard or sketches and a lot of that is physical stuff that you do yourself, and then you translate that back into a digital format.

RESEARCHER repeats question

P7: It's like, normal I guess? Cos I felt like I had the problem there, instead of most of the time we have a problem, it's...this is a thing and it's just there and there isn't a physical representation. Having a physical model was interesting. It didn't feel new, it didn't feel different, but it did feel like it did fit into the same idea.

11. How did you feel about your performance with the puzzles?

P7: Performance? Fine, I guess? Fine really.

RESEARCHER: Some were happy; some were quite angry. It depends. How do you feel?

P7: There's a bit of apathy to it.

RESEARCHER: You did say part of you wants a challenge, and part of you is lazy and wants it to be easier.

P7: I like doing things like that but I'm also quite lazy at the same time, I'll be interested up unto a certain threshold, and then once I feel, my brain thinks I'm spending too much time on that, it'll just go "OK!! Let's try something else"

12. What would you have done differently?

P7: The 1st thing that comes to mind is The Lamp one. In my head, I realised very quickly that the solution isn't one part of something. There was, in my head, there were two parts of it. Something had to change on The Lamp itself, which had to interact with the base itself. The base was solid; it was struck to the table. It didn't look, one of the ridges there. This is sitting here, so it's definitely meant to react with something. But looking more at how the pieces interacted, I stopped with that train of thought fairly quickly.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P7: The choice aspect, if it were that I didn't have the time limit, I would have taken all the clues as I was on each puzzle, taking the next one as I would have needed it as I got stuck. I would have stayed on one and then moved on to the other until they were all done. Because of the time limit aspect, I just thought "I'm going to take this. I'm not going to take all of them, because I'm not here to finish all of them, I'm just here to make a dent into something." The choices were...that's there, I can come back later to them if I can, if I think of something.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P7: I guess it was more stressful…
RESEARCHER: Really?
P7: Because...if you choose to do something and you can't do it, the ownership is on you for not being able to do it, even though you chose it. Whereas if you're a task and you can do it, the ownership is on the task-giver for knowing, or not knowing, that you don't have the necessary skills to finish the task.

15. What was your favourite aspect of learning like this?
P7: Making you fix everything! Breaking the pieces and making sure you have to put them back together!
RESEARCHER: That was a courtesy to get it back to their original state.

16. What was your least favourite aspect of learning like this?
P7: I guess, how I do like the fact that they came apart, but part n' parcel of that was that they were very finicky. I broke The Lamp 3 times.
RESEARCHER: Twice, it was twice I had to put it back in its housing.
P7: It was nice that I could take the pieces apart if I wanted to, but at times, I didn't want to, I just wanted to see what was happening and the pieces would break, so just the finicky-ness of the pieces.

17. Did you learn anything useful to you? What?
P7: I don't feel like I walked away with some a-ha moment or some new outlook but it's definitely something I could look back at, and say "oh this is.., if you kind of think of it in a different way, try and adjust your way of looking at it at a different angle, maybe you'll be able to find something new, the physical representation of it, being able to see it from different sides, different angles is something, I guess, I took away from it.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P7: Not necessarily.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P7: It definitely gave me a representation to call back too, instead of trying to hold the information in...an imaginary state in your head, it's actually a physical state that you've

seen, you've interacted with and you can go back to that memory and be able to remember everything, if you just recall what that situation was.
RESEARCHER: Do you find it easy to remember what you did, even though it was a while ago?
P7: Yes.
RESEARCHER: Do you remember all your lectures easy too?
P7: I do lectures with, instead of lots of notes or lots of listening, I do it with doodles. I turn what is being said into physical pictographs, something like that with words. So, I guess, it may help someone who just listens or just reads notes, do I just kind of do the same thing, I turn every frame into something else for me to remember.

20. Do you care?
RESEARCHER: Is it a good thing?
P7: I think it is, but I think it more comes down to the fact that when you give a child a task of doing homework, they don't want to do it, but if you give a child a game that has similar elements in it, like the cabbage/the wolf/the sheep/the old man in the boat, it's a different way and they do come out of it learning something. They don't realise they have learned anything until down the line and they go "this is something that I've learned already!", so I think it is good.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P7: I guess, I don't really see where it is now, I don't really see it right now, it could be down the line, something I'm doing that needs solving, some process in design I need to do, and then I remember something about this and I could pick it up and bring it over here and use that element in the future, but right now I don't think it really has.
22. How did you feel about the clues, specifically?
P7: In terms of their availability?
RESEARCHER: Yeah, and how you felt about it.
P7: It's nice, cos I find if you have a puzzle and you don't give the person any clues, you're kinda setting them up for failure. I felt like they were nice instruction, they weren't everything, but they were somethings. The only problem with clues is if you start pulling one out and you think of it a certain way, your brain is going to remember it in that certain way. It's the same when we teach music singing, and they learn the right notes, but the wrong words, they'll always remember the wrong words but the right notes, and it's hard for them to switch down the line. It's the same thing with that, if you pick up a clue, you automatically think you should go this way, instead of thinking of the clue.

23. Did that put you off ahead of time? In principal, were you thinking that's what the clues will be?
P7: I think when I take more of them, which is why I tried to say with a singular clue as long as I could...
RESEARCHER: You looked at The Scarecrow ones, you took your time getting from one to the other, you didn't look at 1, and then 2.

C3.8 P8 Transcript

P8: Single: DMD 1st Year

1. How long have you been studying design?
P8: I'm in my 2nd semester, so it's a semester and a half.

2. What do you think defines a successful student?
P8: I suppose it's kind of, in actual college standards, it's if you meet the requirements for day-to-day deadlines, so as long as you meet them, to the college you're a successful student. But, it's kinda different individualised, if someone's failing one subject, but they're failing it by less and less percent, that's still success even if it's considered a fail.
RESEARCHER: Do you think just getting good results is success?
P8: It's kind of the way it's graded, as success in the college at the moment.

3. What do you think defines a successful instructor?
P8: I suppose…
RESEARCHER: Your opinion. I'm not even suggesting that you become one. It's what do you think?
P8: I've seen good and bad instructors, so far. My pet peeve with instructors are those who read off notes to you, especially in lectures. We can easily read notes ourselves. But, a lecturer who won't go into more detail than the text on the screen, it seems just pointless, it's just, like we have one lecturer, I'm not going to name names or subjects, but in terms of lab work, we're being given assignments where we have no idea of what we're supposed to do. We're kinda being told "this is a car, now go and build one. This is an engine, this is what it does, now you know how to build one". Whereas other instructors will go through things, why you have to do something, this is how it works, they'll give you feedback on what you did wrong, how you can improve on, what you did wrong, alternative methods. To get back to the question, a good instructor goes through things, reviews your work and gives you good feedback.

4. Why did you volunteer for this testing with me?
P8: Honestly, it seemed kind of fun. I liked when you taught us as well, so that's a big element. The idea of going through logic puzzles always kind of interests me.

5. How do you think the physical nature of the puzzles affected your reasoning?
P8: I suppose rather than having to just think things out internally and try to picture stuff, you get to actually see the different components rather than thinking "will this work?", you can hold it up to the other objects and "no, this won't fit". It's kind of nice being able to just see your actual solutions ahead of you, rather than trying to just internalise it.
RESEARCHER: This is different from when you reason when it's on paper, or up on a board?
P8: You have to try, with that kind of an object, if you were just given the pieces and then you turn away and you have to try come up with things, you'd have to internalise everything, try to picture how things worked...again the example I come back to is coding. It's nice to see how code affects things, rather than going through pages and pages of code and trying to internalise "what does this actually do?" That's the example I have.

6. How do you think the physical nature of the puzzles affected your emotional engagement?

RESEARCHER: [referring to the classic Farmer/Grain/Fox/Chicken puzzle] That's a logic puzzle. You could argue that a machine would solve that, but a machine would struggle with them [referring to the K'Nex puzzles].

P8: I suppose the main thing is the reward at the end when you solve it is great because you actually get to see the finished structure, It's like...for a long time I wanted to do Business in college and I decided against it because if I do 1000s of pages of work, the one thing I won't have is something nice to look back on, whereas with this kind of course I'm doing now, I like the idea of being able to look back and "oh yeah, that's nice, that's a pretty good thing" and the same thing goes for a puzzle. You can look back and say that worked really well, I liked being able to see how things would play out.

7. How did "Working Alone" affect your thinking?

P8: I always prefer to work alone, to be honest. The whole saying "a rhino is a horse built by committee". When there are too many different opinions going one, that puzzle would take a lot longer, then again it could have taken shorter with someone smarter had figured it out. There was a lot of different ideas I played around with, and if we had to go through, you know, say if there was 4 people, if I had to go through 4 times the number of ideas, it never would have been done on time.

8. How did "Working Alone" affect how you felt?

RESEARCHER: You thinking straight away you would prefer it that way.

P8: I definitely prefer it, but I can see how people might think the pressure is more on them, they have more responsibility, that if they fail at this it kinda seems "maybe I'm not smart enough" but in a group you feel like "if they're not able to do it, it's just a harder puzzle." A group mentality consensus thing, if you know what I mean.

9. Would you have preferred "Working in Pairs"? Why?

RESEARCHER: But, you were ok with…how did you feel about yourself when working alone?

P8: I love being alone.

[REFERRING TO VIDEO NOTES]

RESEARCHER: You started with The Scarecrow one, and you stayed with it until it was solved, then you moved to The Lift, you immediately worked out what to do, took you 8 minutes to actually solve it, because a couple of things didn't work, it went wrong for you, then moved to The Lamp with about 10 minutes to go. After halfway through that time you worked out how the mechanism works. You were assembling a rather complex mechanism for a push-pull thing at the back. Just thinking about the clues...so you solved 2, which is above the average. You didn't look at any clues for The Lift, because it would appear you didn't need to, but for the Scarecrow you were quite quick with the clues. How did you feel about the clues?

FINATAN: The clues were just kinda...when I was going through them, I figured out "OK, this definitely needs to use gravity", and then I looked at the clue and it's "You need to use gravity" The clues...I won't say that they weren't useful, because they confirmed what I was thinking.

RESEARCHER: Well if you hadn't worked it out, they would have been useful.

P8: But at the same time, I could have been going down a completely wrong path and I look at the clue and think "OK, I'm on to something here!"
RESEARCHER: You had no issue looking at the clues? Just referring to other people, some people felt it was giving in. Did you think that?
P8: No, definitely not. The whole point of being able to do puzzles is you want to do it right, so if there's something to help you do it right, then why wouldn't you take it?
RESEARCHER: So you looked at the first two and worked out what to do, so you solved it. You didn't need the clues for The Lift. You did look at the first clue for The Lamp and that was the switch. The second clue would have told you what had taken you another 3 minutes to work out for yourself, so that's ok. It ended up not quite working in the end. That was very good. I was just thinking, one of the things about with your hands, the physical nature. You stared at The Scarecrow puzzle for 7 minutes, then you looked at the clue and then you started fiddling with it, moving the trailer up by hand and so on. That was interesting, because you were saying earlier that it was nice having something physical in front of you, but you didn't touch it for eight minutes.
P8: I'm not really used to this at first the thing of figuring it out…
RESEARCHER: Why didn't you start ripping into it straight away?
P8: Because first I went back to the thing of figuring it with your mind and then I was "wait, I can touch this!"
RESEARCHER: That was interesting, and of course your solution for The Scarecrow was hilarious. I'll send you a video clip of that, it's ridiculous.

10. How did you feel about dealing with physical puzzles in a learning environment?
P8: It's a lot more memorable, I always find.
RESEARCHER: Could you remember the things I was referring them?
P8: Yeah. I can remember everything in detail. I did a lot of sports and that kind of thing, and you get used to muscle memory a lot more than being constantly told stuff, and told to remember it. When you actually get to engage with something, it makes more definitive memories of how that actually works. So I can remember the whole thing about the elevator and how people complained about the taxi and they thought it wasn't going fast enough, but the problem wasn't that it wasn't going fast enough, it's that they were bored. So, it's that kind of story, I probably wouldn't remember that if that just came in a 5-minute part of a lecture, because I would have nothing to tie it back too, so with a strong physical memory, you can remember stuff like that.

11. How did you feel about your performance with the puzzles?
P8: I was quite happy with it. If I got another 10 minutes, I could have made up another really complicated one for the light switch [The Lamp].
RESEARCHER: The complex mechanism was interesting. Did you have K'Nex as a kid?
P8: No. Well I did, yeah. I had one for Christmas.
RESEARCHER: I just noticed several individuals who, because of their preparatory test, building this thing [referring to the pre-exploration K'Nex test]. Some people were looking at me, not even looking at her hands, and they are almost all built complex mechanisms that weren't unnecessary at all, because they could. Do you think that you were comfortable that you like puzzles per se, that that affected your decisions?
P8: Yeah.
RESEARCHER: It's something that's come up several times. You were doing ok. I'd say if you had another few minutes but there you go. You didn't.

12. What would you have done differently?
RESEARCHER: The Lift was great, you did that in 8 minutes, The Scarecrow was great too.
P8: If I had had 1 more hint for the light switch [The Lamp] one, I probably would have understood what I needed to do.
RESEARCHER: Almost everyone who didn't solve it realised the 2nd clue gave it away. Would you have felt better if you solved all 3?
P8: No, because I still enjoyed it quite a lot.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P8: Most definitely.
RESEARCHER: How? Because you didn't skip between puzzles. You stayed with one and solved it.
P8: I went straight for what I thought was hardest. I was probably wrong with that, but...It's kind of, even if I didn't switch around between puzzles, it's that kind of thought that if I go too far with this and then get stuck, I can still move on. It's a kind of reassurance, if that makes sense, to be able to move on. In terms of the clues, it's nice to be given the choice of how much information you want revealed, cos I play a lot of puzzle games, I like that kind of stuff...it's just kind of nice to have some kind of help without being told exactly what to do.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P8: Again, I quite liked it, yeah.

15. What was your favourite aspect of learning like this?
P8: My favourite thing was actually the stories behind them. While it's fun doing this kind of stuff, to actually learn "oh, this actually relates to something real" is a nice little lesson, if that makes sense.

16. What was your least favourite aspect of learning like this?
P8: No.
RESEARCHER: A lot of people mentioned the time limit, which was...I tried to get that so that it would be, not impossible, but pushing it to solve all 3. I was trying to force people into making decisions...2 people solved all 3, out of 31 people. I'd say if I had made it an hour long, half the people would have solved it. People were just short, so most people hated that.

17. Did you learn anything useful to you? What?
P8: Well again stuff like the whole lift scenario. It's good to think that there's alternate ways of solving straightforward problems. Rather than speeding up an elevator, you can make a lobby pretty, and it solves the same problem without touching on the problem itself, if that kind of makes sense.

18. Did you learn anything that was interesting to you, and not just useful to know? What?

P8: It was all kind of interesting. I can't say "that's kind of interesting but not useful" because I find most of the stuff that I learn is useful.
RESEARCHER: If you find something interesting you find something useful?
P8: Yeah.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P8: Yeah, I'd say so.
RESEARCHER: Why?
P8: It just ties back to being able to see what I'm doing, and being able to actually touch puzzles themselves. It's just nice to get outside of your own head and think with your hands.

20. Do you care?
P8: I've always done riddles and logic puzzles, just because it helps with other things. The main lesson I've learnt from here was that there are alternate solutions to very straightforward problems, and that's a lesson that I can take with other stuff. I can't really think of any examples now, but if they come up, I can have that useful information to back-up with and say "you've been given this problem, but is there other ways to fix it without going with the obvious?"

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P8: The actual physical aspect of it, or the entire thing?
RESEARCHER: The whole experience.
P8: Generally, it helps being able to do stuff that isn't in your mind, or isn't on a computer. It's nice to be able to design something in the real world that you can see exactly how it changes as you do it. Again, I keep going back to coding, but a lot of the stuff with coding you can do something and not know what you've just done, you can delete one bracket and everything is broken and you don't know why. Whereas with this, if you move 1 piece, you know exactly where that piece is supposed to go, and where you're keeping it, and what it actually it affects, so the whole idea of your being able to see every single element, and manipulate any element you want and see how that affects the entire thing is kind of a nice part of it.

C3.9 P9 Transcript

P9: Pair (with P10): iMedia

1. How long have you been studying design?
P9: 1 year.
RESEARCHER: What did you do before?
P9: I've been working for a while as an Interior Designer, I'm good with drafting, I'm a pretty good drafter and I then worked in the cartoon industry, compositing for 2D cartoon series, and educational software for kids. Also I made games for preschool kids, in order to help them learn the alphabet, numbers, count to 10, and stuff like that.

2. What do you think defines a successful student?

P9: A successful student? I think that that's the person who manages to comprehend, who gets the best out of every module. I think it's...what offered is general knowledge that you have to comprehend in order to work in that field and be successful, be good. I think a successful student, if there's with a certain module that they're not very good at but could define what is there for him and take out of it and make the best out of it. I do not speak really very good but...

3. What do you think defines a successful instructor?
P9: That is the person that can transfer knowledge. Who can communicate knowledge between himself and his pupils, I think.

4. Why did you volunteer for this testing with me?
P9: I was very...eager to see what are these games are. I've seen the picture actually so "Wow, it looks like LEGO City!" so I was really very interested to see what it is all about. I didn't have a clue what it's all about, I just saw the picture and it looked very interesting.

5. How do you think the physical nature of the puzzles affected your reasoning?
P9: I liked it. I think that was great, to be able to actually try out how does this thing work and to think about how to solve the problem. Much better than just thinking about an equation. I am looking at it there is an x, there is a y, and now I have to figure out. This, for me...I am a visual type and I would prefer.
RESEARCHER: The Batman [The Scarecrow] puzzle, despite the fact it was physically easy to do, you were one of the only ones to pull the string up and down to see. Several people didn't touch it, and were clearly thinking and turned the motor on to see, so you were interacting with it physically.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P9: I felt encouraged to explore, to try out, to see how this thing works.
RESEARCHER: Why?
P9: Why?
RESEARCHER: Why would you feel that way?
P9: There was a question, solve the puzzle, and I did my best. I felt comfortable with it.
RESEARCHER: Despite the fact that it was physical, some people still stared for 10 minutes, in the same way if I'd just put a photograph up there, stare at it and not touch.
P9: It didn't cross my mind that I would break something. I'm pretty good at making LEGO with my daughter often. So, it's working.

7. How did "Working in Pairs" affect your thinking?
P9: I felt very comfortable, and there is another person here to collaborate, to think aloud along with me, so that we might come up with the idea faster than if I'm alone, perhaps.
RESEARCHER: That's what you were thinking?
P9: Comfortable.
RESEARCHER: Were you thinking this before you started to work on the puzzles, or during? You were expecting it to be this?
P9: I guess, before and during this session.

8. How did "Working in Pairs" affect how you felt?
P9: Well, actually I didn't try do them on my own, so I can't compare. But I think I would like, if you're asking me if I would be more comfortable if I was on my own, I don't know because I didn't try, but when the project is ahead, I feel comfortable to work, cooperate with colleague. I don't mind if something could be done alone or in a team. It just depends on the task, if it's meant to be to do only with one person, or a team, I feel comfortable with that.

9. Would you have preferred Working Alone? Why?
P9: I don't know; I think both are nice.

9a. Were you comfortable with voicing your opinion?
P9: Yes, of course.
RESEARCHER: Some aren't. Some are very shy, they think they might be wrong and they don't want to say. You were fine?
P9: I felt comfortable all the way, yeah.

10. How did you feel about dealing with physical puzzles in a learning environment?
P9: Great! I think that great, this is like...I really liked it yeah. I was very curious to see. I just saw the picture, "oh my God, a tiny LEGO City!" I really liked it. I was really interested to see what it was all about. At the end when I discovered what it was all about I was even more...like you said before I wasn't afraid to touch, to see how things would work.
RESEARCHER: You were very excited, you started dancing when you solved The Scarecrow, you were very happy!

11. How did you feel about your performance with the puzzles?
P9: I guess I was a little bit disappointed, because when I arrive here, I think "ok, we're going to solve them all" but, then again...it was great. It was very interesting. I liked it.

12. What would you have done differently?
P9: Perhaps look at the drawers.
RESEARCHER: The hints?
P9: Yeah. Actually, I wasn't aware of the time. I thought "there's enough time, there's enough time", then "arghh!"
RESEARCHER: You only looked at 1 clue out of 9, and that wasn't until 40 minutes. So, you solved The Scarecrow without looking at any clues. You didn't attempt The Lift because you ran out of time. 1 clue out of 9…Why did you not look at the clues?
P9: I don't know. Because it was all tangible? I thought, probably I thought I don't have to? I'm not sure everything was there and I thought "why should I look at the drawers?" It's all here, it should be visible. I guess...I wasn't actually thinking about that.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P9: I think that...perhaps these clues...I didn't ask actually...but I thought if I go to see the 3rd one, maybe it would be like "there is a clue and you didn't solve it for yourself".
RESEARCHER: So that's why you chose not to look at them?

P9: Now that I'm thinking back, I think that was the...I actually didn't ask and I didn't know that, but somehow I presumed that the 3rd...
RESEARCHER: It kind of does. It doesn't finish the game, but they pretty much tell you how to do it.
P9: I was thinking “let's do our best and let's try to solve it without peeking”

14. How did the choice element, the ability to direct your learning, affect how you felt?
P9: Something that I postponed and thought that would reveal the clue, but that's like...comforting, so I had that help if I cannot figure out anything.
RESEARCHER: It's interesting, because people have different views. Most people liked the choice. Some people would have preferred me telling them which one was easiest to do, things like that.

15. What was your favourite aspect of learning like this?
P9: What we discussed. Everything is tangible, and you can try out the mechanism to see how it works and try to develop the topic and how it works and what should I do to reveal the puzzle.

16. What was your least favourite aspect of learning like this?
P9: Least favourite thing about it? I don't know. I don't think there's any...
RESEARCHER: You don’t have to be polite! If there was something you hated, you should say. Some people didn't like the time pressure….
P9: Oh yeah, I didn't like that.
RESEARCHER: You didn’t like that, no?
P9: No.
RESEARCHER: Why you didn't like that?
P9: Because I was comfortable, I thought is enough time and then I ran out of time. It’s always...not a comfortable feeling.

17. Did you learn anything useful to you? What?
P9: I haven't thought about it.
18. Did you learn anything that was interesting to you, and not just useful to know? What?
P9: I was impressed how everything...was built in this context, to resolve a puzzle. What did I learn actually? It was about the knowledge that we already have, but maybe it's another media to express it. Maybe that can be a bit like how to solve this, how to make it happen. That’s it.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P9: I think it made it comprehend more better, then just reading about it.
RESEARCHER: To an extent you would think it had to, but that's why I'm asking.

20. Do you care?
P9: Of course.
RESEARCHER: I thought you might.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P9: Yes, I think they are good examples.
RESEARCHER: Why do you think it's helped you?
P9: Well...could you repeat the question?
RESEARCHER: Did this help you more fully understand...reframing was a very specific question. The idea of how designer needs to think...do you think you'll understand that more now? Instead of me just telling you how a designer should think.
P9: Yes. I think the most important part is to try it for yourself.
RESEARCHER: This is your opinion. There is no right or wrong answer. Do you think that trying it out yourself, it was better?
P9: Yes, of course.
RESEARCHER: Even though you...solved one, and you were very close to solving another, do you think you would have understood it better if you completed all 3 or do you think…?
P9: Maybe perhaps, I don't know. I don't see any pattern in solving all 3 actually, so I guess the point is to try, and that's the main point. Even if we didn't solve any of it, we would try to work from 1, 2, 3 [waves at the puzzles] and then "we really can do it!" But, in the end we will learn how it's supposed to work, and then we will learn how it's done, how...to solve the puzzle. Yeah, that's what I think. I think also it's very encouraging when you solve one, then you're eager to solve the 2nd one, because now you think "I can do them all" but I think the point is to try and think about, and do your best.

C3.10 P10 Transcript

P10: Pair (with P9): iMedia

1. How long have you been studying design?
P10: For about 5 months here. Prior to this, I studied Engineering, so this is the 1st time I'm into Design as such. From September 2017, I'm into the design world.
RESEARCHER: I knew it was Engineering because of comments you made during the testing!

2. What do you think defines a successful student?
P10: Someone who can achieve the goals they set for themselves, I think would make them successful. If they have identified what their stance are and what's not, and what works for them and what doesn't, and they've figured it out it that this is something that wants to be doing for now, and they know that they can be doing a lot much then maybe other students, maybe themselves prior to that. So, that might make him a successful student, just thinking if I am considering myself then I am considering myself successful if I can achieve the goals I set for myself, respectable to what the actual standard goals are.

3. What do you think defines a successful instructor?
P10: Someone who can actually get his thoughts across to the student, the trainee as such. If you have something in mind and you can get it across to someone, then you were successful at that.

4. Why did you volunteer for this testing with me?

P10: Because it sounded a lot of fun when you said we will be solving puzzles, and then having just had one class with you, I've seen that you are, as a person, really fun to work with and I want to explore that as well, I wanted to see what these puzzles are, cos I had the opportunity to see you build, once in the Design Studio where you had kept it, and it seemed amazing and finally it was out for the public, we could be testing with it!
RESEARCHER: Once I stopped breaking it...

5. How do you think the physical nature of the puzzles affected your reasoning?

P10: In some ways yes, because in the light one [points at The Dalen Lamp] I kept thinking I cannot... this cannot be the answer, although I kept pointing to the middle one [the middle bar, removing it is part of the solution] and said we have to break that, I thought that it couldn't be the answer because it was strong, "no you would have made it a little bit shaky, or it would be made of different material if that was the answer!" I think because of the limitations for me there came because of the material used there. I thought "this is strong enough, that is not the one I should be breaking" It did affect my reasoning one way or another, but that's not an excuse for not actually solving it.
RESEARCHER: The questions are trying to discern whether...how much of a difference it makes, instead of me describing it in a lecture, and you having to think. When it's in front of you, it's physically there.
P10: Yeah, and it allows me to explore. So, in a way it allowed me to...I was in the problem when I actually was working with the physical objects, that was me trying to solve something and learning in the process, as opposed to you telling me something. So yes, they encouraged me to play around with it and learn in some ways. They also discouraged me from finding the answer, because I felt this kind of structure that doesn't really make that the answer, and it must be something else.

6. How do you think the physical nature of the puzzles affected your emotional engagement?

P10: I think I felt good playing with it. It was something that was there, I could feel and it made me feel more engaged, as opposed to just hearing words and maybe just seeing something...somebody else playing it also wouldn't be as engaging as it would be with me touching them, feeling them, and actually playing with them.

[REFERRING TO VIDEO NOTES]

RESEARCHER: You started with The Scarecrow, didn't look at any of the clues. You suggested a couple of times that "should we look at this clue?" but you still solved it. Then you went to The Lamp. You focused on that for a while...you eventually looked at the...
P10: Barely managed to just go to the last puzzle.
RESEARCHER: You looked at the clue, and then you ended up going to the last puzzle. So, you looked at only 1 clue out of 9, because there was 3 for each one. You wanted to, you suggested [it] a few times.

7. How did "Working in Pairs" affect your thinking?

P10: It helped me in a way, because I think we built on each other's sentences and statements and that's how we applied ourselves to the problem solving, for the first one at least. I think if it was just me, I think I would have just stared at the whole thing for the longer time and taking more time to do something. Maya suggested that we could hide it, so one thing led to another and when she said something and I built on it and

the same thing continued for a while, so it kind of helped me to think better or in different ways because I was in a pair. It was somebody else providing me the clues.

8. How did "Working in Pairs" affect how you felt?

P10: I don't think it affected in a very different margin when it came to my feelings about it because I think I would have enjoyed the process equally if I done it alone also. Because, at the end it was both of us giving it a shot and then seeing what would work for us. So, how I felt didn't really have anything to do with it us being in pairs.

RESEARCHER: You made suggestions about accessing the clues and you were ignored, as in the video you were saying "will we do this?" and there wasn't a yes or no answer, it was...not listening to you.

P10: About that, I think I'm happy that it actually happened, because I would have maybe given in faster and then seen the clue and then maybe still not figured it out. So the fact that we actually can solve at least one of them without looking at the clues did make me happy at the end of it. That was because she didn't encourage seeing the clues and even when I suggested twice or trice, she didn't really seem to approve of it, which was when I felt "yeah ok, let's not do it! Let's not give it!"

RESEARCHER: With The Lamp, you said what to do, earlier than both of you said it.

P10: Maybe, or maybe not, I would have arrived at the clue faster, or the solution faster.

9. Would you have preferred Working Alone? Why?

P10: I think I'm open to both of them giving a choice. I would like to try the 3rd one [The Lift] alone and see if I take longer or shorter to arrive at the solution. That's just the curiosity part of it but it wouldn't affect how I felt, or whether I would have preferred to be alone. I don't think that's a preference, I would have enjoyed it in either way.

9a. Were you comfortable with voicing your opinion?

P10: Yes, definitely. Whether she listens to me or not as I was going on with my opinions!

RESEARCHER: Everyone who has come in a pair has come with a friend of theirs, so it's not...

P10: Not really that awkward. But then it would be different if I had to work with some stranger.

RESEARCHER: Would it be? What if you had to work with [points at] Kim [office mate]?

P10: I would maybe hesitate much in voicing out my opinions then, because then the factor of being judged would have come into the picture and I feel like...I do give a suggestion and then it would turns out wrong or maybe takes us to a...longer process, and I feel fear that maybe she judge me, that "oh, I would have done better if this girl wasn't with me!" Things like that might have come into it.

10. How did you feel about dealing with physical puzzles in a learning environment?

P10: I would love it. Because I think I learn better when it's that way then just reading theory. I think I can remember it better. I do learn equally well when I'm just reading a lot of papers and I do get to know other people's point of view, but it comes to remembering every point that has been told in a paper, it would be a different thing and maybe seeing, it would still be a different thing. But when I've done something, then I know what I did, and that makes me feel more confident about it. Even if I messed up the whole thing, even if I didn't get the answers right, the whole process as such would

have given me insight into what I should have done. So, it's still a better learning for me when I do things, as opposed to when I just read or see or listen.

11. How did you feel about your performance with the puzzles?
P10: With the puzzles? Ok-ish. Not that great.
RESEARCHER: Well, you solved 1, and you knew...
P10: Nearly solved!
RESEARCHER: ...knew what to do for the 2nd. Yes. That was good.
P10: Once I knew the answer, I felt a little sheepish there, because it was there, staring, staring right into my hand and I didn't do it. So, I just felt it was ok, but it could have been much better. We could have solved it easier considering we were in pairs. It wasn't just me and my own thinking alone. So, I feel we could have done a better job, the two of us going at it...we could have tried because there was no stopping us. You kept telling us, encouraging to just go ahead, break whatever. You didn't give that thing "be careful" or if you're told something like "it's fragile!" Maybe that would limit, but it wasn't the case so I feel bad that we didn't give it a shot and just break it.

12. What would you have done differently?
P10: Just go for it! I would have just gone for it. If this was given another chance as such, then maybe I would break this.
RESEARCHER: Break everything!
P10: Break it, try it!

13. How did the choice element, the ability to direct your learning, affect your thinking?
P10: I think the choice you gave me delayed my whole procedure, because I didn't know what was what, although you had outlined the process as such, I didn't know what had to be done with respect to each of them, and how long it usually takes. But then, obviously there's no right...or wrong answer here. There's no time limit, each person maybe thinks in a different way, comes up with answers to the different puzzles. So going by that, I felt it was a different thing for me, because if you told me "you go for this 1st, and that 2nd and then this" I would have...it would be streamlined and I would have divided it in an equal order. And I would have given this much time for this, this much time for this. Because then, because it was our choice, somewhere at the end of it...the disappointment also was on us and it felt even more bad, as opposed to if you had told me, I would have "Researcher made me do that, that's why I didn't get it", but here it was I chose to do this, and I took a lot of time here and it all falls on me.

14. How did the choice element, the ability to direct your learning, affect how you felt?
RESEARCHER: Did you like it that you could choose, or would you have preferred more structure from me?
P10: I think I would have preferred more structure from you, because I am not that great at choices. I usually struggle when I'm given 2 things and told "pick". My mind is in conflict and I end up regretting what I pick. That's usually the case with me, so I would have preferred structure from you.

15. What was your favourite aspect of learning like this?

P10: The fact that we could be there, we could do things on our own and there was no stopping us. It's just like a playground, you play and you're learning at the end of it, so that was the best part about it, me getting to work around and do things. And it was not just play at the end of it, because you did tell us what the bigger picture was, and what we'd actually solved. So, it was good experience I think because I actually learnt something at the end of it, by playing! So it was good.

16. What was your least favourite aspect of learning like this?
P10: The least favourite was there was this competition element there and the time limit, that's when...it takes off the joy as well, because I want to be succeeded and I want to be doing it, and I also know that I'm not doing it because I'm running out of time. I didn't manage the time well, so a lot of factors that are there...pointed to me that "you didn't do it! You didn't do that!" The disappointment. The competition thing!
RESEARCHER: What competition was there?
P10: We had to do it in time and our goal was that, because there was 2 of us, we will have to be finishing the 3 of the puzzles. And we also got to know from you that there are people who single-handedly managed to solve all of it, then surely...then we couldn't do something like that, so that competition with people who have solved it and we don't really know them, but then it's still there.
RESEARCHER: That's a part of it!

17. Did you learn anything useful to you? What?
P10: Obviously, I didn't know about any 3 principles that you actually told and what happened, [reference to The Scarecrow/William's F1 Team] and just the thought processes as such because one team actually thought of it and the others didn't. To know that, so that it opened a lot of possibilities here, as in maybe I'm doing certain things like this in my life...the answer is to just think in a different way, just try out the main things possible. I think learning has been in a lot of things, one is the factual learning, which you told that the end of it, that this was the principle behind what I did, what I designed here. The other learning is where I learned how I am in a team environment. I learned how I could be, and about the time management and everything. Just the thinking maybe, so a lot of learning, in different compartments.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P10: I think everything is useful in one or the other way.
RESEARCHER: You are such an Engineer.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P10: Yes, I do think that. Because if you just told me about the whole thing and without me having tried it...
RESEARCHER: Because even with The Scarecrow, you did pull it up and down with the string. You added constraints, because of the physical nature, you thought it was too strong, and that was the whole point! That it could be made weaker!
P10: Yes. When you talk about that….
RESEARCHER: You go "aghhh".

20. Do you care?

P10: It was interesting. The factual learning at the end of it, I don't know if that would really help me now. At that moment, did it help me with something? No. But it's always good to know something that we don't know. That way it was a good learning at the end of it. I'm happy about it.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P10: Yes.
RESEARCHER: Why?
P10: Because this was...this wasn't even the exact reconstruction of the problem. It was reconstruction but in a different way and everything. It just kind of made me think in what different ways can someone be thinking? A simple play-toy made them give out answers. If I could apply whatever I do here to a lot of other areas of my life, then I could actually be discovering so many things. And that's what design thinking is for me, the little bit I know about design thinking. I felt it's way too broad and open-minded in its own nature, not the human perspective, but the field as such. But, it makes you think in different ways and apply it also in different ways, so there's no 1 particular way of doing things, but when you learn something here can be applied in a very useful way and it's a phenomenal thing to be a solution to something else. That was an eye-opener for me on the design thinking perspective, but I still haven't done anything much on the lesson that I've learned. Actually taking it and applying it, I don't know if I'm doing it at all.

C3.11 P11 Transcript

P11: Single: DMD 4th Year
1. How long have you been studying design?
P11: This is my 4th year studying design in 3rd level.

2. What do you think defines a successful student?
P11: Well from an academic point of view, I suppose a successful student is someone who gets good grades very simply.
RESEARCHER: What do you think?
P11: I think someone who engages with actual work and really gets to understand it, cos I know people who are actually really good at what they do, but they mightn't necessarily get the best results in their course, because everyone has different strengths. So, I think... someone who kinda takes the opportunity to learn when they can and takes bits, the efforts to learn other stuff outside of the actual academic stuff as well. Someone who is actually motivated to learn would usually define a successful student, if that makes sense.

3. What do you think defines a successful instructor?
P11: I always find us, especially with lecturers, if they can relate to the students in a way. I had one lecturer, can't think of his name, but he used to bring everything back to comparisons to topics that were relevant, think it was Breaking Bad in first year. He brought everything back to something like Breaking Bad, and so a lot of people would have been able to relate to that. I was able to relate to that. When he was describing sociology and different theories, he would use comparisons from movies that was

relevant to us, so I thought he was really good because he actually made the effort to relate with the students in order to help them understand, if that makes sense. So, I would define a successful instructor as someone who can really get their point of view across in a way that is easily understandable for the students.
RESEARCHER: Professor Devereux I think.
P11: Yeah, Eoin Devereux.

4. Why did you volunteer for this testing with me?
P11: It looked like a bit of craic, and I heard other people who had done it and I know that other people hadn't completed and so I wanted to know if I could complete it, so there was a bit of a challenge.

5. How do you think the physical nature of the puzzles affected your reasoning?
P11: I think it was easier for me to kind of understand it straight off, as it was a physical thing that I could just go to and I could see every aspect...It didn't take us much time to understand it, because I think, personally, if I have a problem written down or scenario, I'd read through it and then by the time I get to the end of it, I've forgotten what I've read through, if that makes sense. So, the fact it was actually there and I could look at it and engage with it and visually understand, rather than just trying to think "ok, was has to be done here?" Once I figured out, for example, the first one [The Lift] "ok, this has to get down before that gets to the end", that just made the whole problem straight away, I knew exactly what I had to do, so I found that it was very quick in that way, for me to understand...so I think...does that answer why it affected my reasoning?

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P11: Well I think I had a bit of an emotional, competitive side going into it because I wanted to complete everything, and I think that I was able to...I think that I felt that the problem was mine almost, because it was me who was doing it and I had this in front of me and it was my job to finish this and to complete all these...this problem so I kind of felt emotional I was a little bit more attached to us then if it was just something that was on screen that I was thinking through, especially in a group of a lot of people, just because I think the fact that I was on my own as well, definitely felt like this is my problem and I have to do this.

7. How did "Working Alone" affect your thinking?
P11: Yeah, I kind of see...the way I work in Design, I like working alone cos I don't like other people's...I usually would be headstrong with my own ideas, but I do like to work alone making my own design decisions and all that, in problems I like to be able to do by myself so I think that it kind of gave me a freedom of thinking, if that makes sense, that I wasn't having to consider other people's opinions or views on the problems, that I was able to focus on my own trying to fix it.

8. How did "Working Alone" affect how you felt?
P11: I think it added to the fact that this is my problem again and I have to fix it myself. So I think, now I always would...I like doing stuff on my own, but then getting feedback from other people, so I think if I was working with someone else, the ideal scenario would be for me to go "ok, I'm going to try this", and then when I get really stuck, ask for a second opinion, like the clues. But working alone, I kind of felt like if you do what

I want really, it was up to me. I think, not that there was any pressure or anything, but I felt like there was more...I felt there was more onus on myself to really be motivated to finish it.

9. Would you have preferred "Working in Pairs"? Why?

P11: No. I prefer working on my own, but I would have liked an opinion every now and again.

[REFERRING TO VIDEO NOTES]

RESEARCHER: It was interesting, because you started with The Lift and you solved it without any clues in 16 minutes, so that's exactly on schedule. Then you moved to The Lamp, you were asking me were there multiple ways to do it, but...it was interesting you...I have down here that at 16:30, you move to The Lamp, and I have down "If the puzzle was not solved, was just thinking correct?" At 20 minutes, meaning 3½ minutes later, you said out loud what the problem was, and how to solve it. Not exactly, but you pretty much expressed, you knew what to do. After a couple of minutes, you understood how The Lamp worked, you pretty much said it out loud. Then you were another 10 minutes, nearly 15 minutes fiddling with it before you open the 2nd clue, and you were still a bit stuck, which I was surprised at, because you had said after a few minutes what the problem was.

P11: I felt like I understood how to...what had to be...how it was solved, but I didn't know how to go about solving it.

RESEARCHER: That was interesting, I would have thought the hard bit, you solved immediately and then you were a bit stuck, even after looking at the 2nd clue. So, you looked at the 2nd clue, and you went "phewewew! [Exasperated sound]". It was annoying you, so you moved on to The Scarecrow and solved that with no clues. But you didn't really have time to get back to The Lamp. You ended up building what was quite a complex structure at the back of The Lamp. Why did you do that?

P11: I think I was overthinking it, almost. I think I was really kind of...when...it's been giving me nightmares. When I think about what I was trying to do in order to fix it was very complex.

RESEARCHER: It was like a triggering mechanism.

P11: And I found afterwards there was a very easy way to do it, just a very simple option didn't click with me and once it didn't click with me I had it in my head "this must be more difficult" and went about this really complex way of doing it.

RESEARCHER: I can feel the bitterness!

P11: Yeah, yeah, still annoying me.

10. How did you feel about dealing with physical puzzles in a learning environment?

P11: Well I personally would like a challenge. I like puzzles...I do like when in lectures where they give questions, not exactly puzzles, but something that would get you thinking when you're in lectures, because I would tend to zone out and be thinking of everything else apart from the lecture, and then when they ask a question, it's "what's that?", and it kind of brings your attention back into it, and the fact that it was a physical puzzle I would find it a lot easier to understand the problem at hand straight away by saying "it's very simple this has to do this"

RESEARCHER: Do you find visualisation difficult, or do you just find this easier?

P11: No, I find it easier, as in I would find...if I saw a load of clues or a load of instructions written on the board or on a piece of paper, I'd...just to make sense of that would take me a lot longer than seeing something like this, just understanding the

mechanics of how this has to do this. Because sometimes when I'm reading through things, it's one thing that I would do what I have a design problem in front of me, or if I have something like a riddle or a puzzle, I'll write down exactly what it's asking you, trying to figure out...so I think there was instructions with this, saying a big long thing saying "these people need to get there before a thing", and by looking at it I felt it was very easy to say "ok, so this has to get down here and this is exactly what you're asking you to do this", so it doesn't really matter how many people are there, what brand of taxi it is! It's just understanding the actual problem at hand, I felt that to be a lot easier by being able to visualise it and see it in front of me.

11. How did you feel about your performance with the puzzles?
RESEARCHER: You solved 2 of them, which was better than average.
P11: I think I spent about 5 minutes on the first one [The Lift], before I actually properly understood...I understood the problem, that the idea was to get the lift down before the car, and then I understood that you had to either speed up the lift or slow down the car. So, I got that very quickly. The method of slowing down the car, I didn't click that for a few minutes. I was trying to build on to a different part to slow it down, which didn't work in the end. I think on the 1st one, I think I performed well on the first one. I was happy with it. The 2nd one, overthought everything, got a bit flustered and kinda just didn't get in the end, I ended up over thinking. If I had told myself "just take a step back and see what exactly needs to be done", I think I would have solved it, and the last one was...
RESEARCHER: Maybe if you've been in a pair. That hasn't quite worked out the way I thought it would, but in principle, yes, you did The Lamp [clicks fingers] like that, if...and you understood how The Lamp...you did The Lift, then you understood how The Lamp worked, then you looked...yeah, if...with a bit of...maybe if somebody...if you'd explained to your partner how The Lamp worked, they might have come up with a simple solution and then you would have been...because you solved the other one, especially after looking at the 2nd clue, that didn't do anything for you, which is odd because that's usually, the people who didn't solve The Lamp usually didn't look at the 2nd clue, and once they looked at it, they went "a-ha!". You were locked into a way of thinking, were you?
P11: Yeah, pretty much.
RESEARCHER: No wonder you're angry.
P11: And the last one I did [The Scarecrow] really quickly.
RESEARCHER: You were fine. You didn't use any of the clues.

12. What would you have done differently?
P11: I would have stepped back and I would have thought about it again. I would have gone back to the drawing board, in a mental sense, yeah...that's one of the things I would have definitely done because if...not be...I was stuck on a certain way of thinking, and in the end of The Lamp, I was "ok, this has to be solved this way", but I never actually took a step back to think of the bigger picture "how else can this be done?", I was focused on my own way.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P11: I think that the way you introduced them to me, when you're explaining them, I think I went about them that way. You told me about each one, and I tried to go about them in that order. I don't know if that's relevant?

RESEARCHER: That wasn't significant at all.
P11: But I think that I had this freedom to move about the place. When I was on The Lamp, I was "ok, I'm running out of time!", that I could just leave it and go on to the next one, I didn't have to solve that to go on to the next one.
RESEARCHER: You spent the same amount of time of each machine. You skipped to The Scarecrow with enough time to finish it comfortably.
P11: Yeah, so I think that it took a bit of pressure off me, that I wasn't...just to bring it back to when I was in Leaving Cert, I did Accounting, and if you make a mistake in one place it messes up the rest of it, and the fact that I could leave it there, forget about it and go back to try something else...I think that it...I...liked that.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P11: I don't know really…
RESEARCHER: You were very slow to look at the clues. Why was that?
P11: I'd be stubborn. I didn't want any help. And then when I realised, I probably realised a bit too late that I needed help, that I wasn't going to solve it without the clues, so I think my own stubbornness came into play there a bit.
RESEARCHER: Did you like the idea that you didn't have to look at the clues?
P11: Yeah.
RESEARCHER: Did you think it would be more of an accomplishment...
P11: Yeah, definitely yeah.
RESEARCHER: Yeah. Some people commenting on that, they were treating it like a game, and it was giving in.

15. What was your favourite aspect of learning like this?
P11: It was fun and it was different, like I didn't actually know that I was learning from it. I just thought of it as, this is a puzzle, a game that you go away and do and you play with it. I never actually...it's not until now that I'm realising I learned anything from it. That wasn't something I was conscious of, that I was learning. So it was kind of disguising learning.
RESEARCHER: Yeah. Entirely deliberate.
P11: Which I definitely liked, it didn't feel like it was anything academic at all. I don't know if it's just the way it was presented or because it was different from what I'm used to with academia, but yeah.

16. What was your least favourite aspect of learning like this?
P11: The Lamp. My least favourite aspect of learning like this?
RESEARCHER: Yeah...or even this exact event. Does the fact that you failed?
P11: Yeah, the fact that I failed was, now that's just my own competitive nature.
RESEARCHER: Yeah, cos that was a very loaded way of putting it. "You failed!" and you're going "yeah, I failed!!!"
P11: Yeah, didn't like about it? I dunno really. That I didn't complete it was the only thing I didn't really like about it. That's about it, to be honest.

17. Did you learn anything useful to you? What?
P11: I learned to take a step back, and look at things differently now and again, especially when there's a time-limit or a deadline due. What I actually did was I went in completely the wrong direction, and I wasted a lot of time doing the wrong thing before...and I never ended up realising the right thing, whereas if I had taken a step back

and could have refreshed my thoughts and try to think outside the box, rather than the very set way that I had thought...
RESEARCHER: You did figure out what the problem was, you were just stuck without...

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P11: Not really. I learned how to play with K'Nex, I didn't play with them when I was younger, so...
RESEARCHER: It's interesting you mentioned that, most of the people who, to their detriment, tried to build complex structures with moving parts, their problem was actually they were quite familiar with K'Nex. Because they could build things that swivelled…
P11: They would…
RESEARCHER: They were instantly thinking "I should do it this way" None of their attempts worked. I would have been surprised, but happy, if they built something complex that worked, but none of them did. Most...the ones who did that said they were very familiar with K'Nex. In their preparatory game, they were very quick. You still got into building stuff, even though you weren't used to it.
P11: Yeah.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P11: Definitely.
RESEARCHER: Why do you think that helped?
P11: I think, I find a lot easier to learn from engaging with stuff, and actually...so for example, I'd never pick up a manual for something, I'd try and use it straight away. I think the fact that I can just go and see the problem, rather than trying to think of it or trying to make sense of this, I found a lot easier to make sense of what's been asked by looking at the physical thing.

20. Do you care?
P11: It's always good to learn. Do I care, maybe not as much...?
RESEARCHER: As much as what?
P11: As in...I think if it was something very relevant to me, or if I think what I did learn was very, very, very beneficial to me, I would have cared, but I think that I didn't actually know I was learning, so I didn't really care that much coming out of it, that I had learned anything..
RESEARCHER: You just want to do well?
P11: Yeah.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P11: I definitely understand you need to step back and consider different options every now and again, so...
RESEARCHER: What you did was a part of it.
P11: Kind of, yeah so.

C3.12 P12 Transcript

P12: Single: iMedia

1. How long have you been studying design?
P12: I did a Product Design degree from 2008 to 2012, and then worked in various bits since then, so 8 years, give or take.

2. What do you think defines a successful student?
P12: Flexibility and willingness to learn, and willingness to try and fail. That's pretty much it. The more you try, the more you fail, the more you practice, cos when you're a student you don't have the ramifications of actual consequences when you fail, whereas in the real world you do, so when you're a student, you need to take those chances when you have them.

3. What do you think defines a successful instructor?
P12: Flexibility and willingness to admit when you're wrong, and also being able to clearly articulate your ideas for a variety of ways, for different learning styles. If you're inflexible and you only like one type of lesson, then you're...it's not a good instruction. Because I've briefly being a ski instructor and one method does not work for all types of students, but sometimes you have to admit that they know stuff that's better than you. That's just my experience.

4. Why did you volunteer for this testing with me?
P12: It sounded like fun. I don't really need much more motivation than that.

5. How do you think the physical nature of the puzzles affected your reasoning?
P12: It definitely requires you to think a bit more laterally because when you end up staring...when you stare at a screen all day, you tend to think very two-dimensional way so the physical nature of the puzzles forces you to visualise solutions a bit more, although then again, it did cause me to hesitate to make adjustments and actually getting stuck in because physical things require a bit more...there's no undo nature, no undo button in physical objects, so positive and negative, in that you need to work harder to achieve those results but you also need to work harder to scale back, if you want to...personally if I want to take it a lot of different directions, then you need to try one thing and then go back to the start and try another thing and go back to the start and with digital things, that tends to be a lot easier.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P12: The materials they are made out of, I was very familiar with from playing with them as a child so that definitely fired the old nostalgia triggers. They're bright and they're colourful, it's not just a piece of paper with some questions on it, so it feels more fun. When you're having a bit more fun, you think more creatively, so I definitely think it frees up a lot of your thought, and it means you're not under as much stress then you otherwise would be.
RESEARCHER: You mentioned about the undo feature, and I get what you mean, but considering you knew what the K'Nex were, there is a kind of undo feature.
P12: There is definitely, well in this particular toy alright, my familiarity with them definitely...overcame the initial interaction barrier a lot faster.

7. How did "Working Alone" affect your thinking?

P12: I would have hesitated a lot more. I enjoy working in groups a lot more, if they're also engaged with the subject, there's someone to bounce ideas off, but I would say if you're trying to bounce ideas off yourself it doesn't really work as well. If you remember when I was doing the puzzles, I was just trying to talk through all of the steps from start to finish and it helps when someone else is there to try and help you over the speed bumps, because when you're on your own, those bumps take a little bit longer to circumvent. Yeah, so I found it more difficult. I prefer working with people.

8. How did "Working Alone" affect how you felt?

P12: It would have made me a lot more aware of my limitations, as working alone...when you had that bump, when you hit the wall, you're a lot more aware of there's an answer here and I don't know how to get to it.

9. Would you have preferred "Working in Pairs"? Why?

P12: Yes.

RESEARCHER: OK. Why?

P12: It would have been more fun. I feel like, when there's a variety of thinking there, it's...the co-operative nature of it would have been a lot more engaging, I feel.

[REFERRING TO VIDEO NOTES]

RESEARCHER: Looking at the things you did, you solved The Lift, you actually articulated the correct solution out loud for the two you didn't solve, because I have the times marked.

P12: But I didn't notice that if somebody was there perhaps I would have…

RESEARCHER: You began by saying, you said you were going to do very badly, you said that out loud, and yet...it was interesting that you went to The Lift, had a good look at it, then went to The Scarecrow, had a good look at that, then went to The Lamp, had a good look at that, then started with The Lamp, but one of the things you did which was interesting, you worked out...you said what the solution was out loud, and then you started building what I would call an overly complex triggering mechanism, but it's something several people did. The connection seems to be that they all had K'Nex when they were a kid. It was because they could, even though it turned out to not be necessary. Then you went to The Lift, you solved that one. I did notice there was lots of staring, as opposed to the option of fiddling with the K'Nex. Lots of thinking, and there was an option to break things and put them back together. You were able to vocalise the solutions really quickly for all 3, then it just took a while to get going.

P12: I think that comes with practice, especially I might not have been able to do that if I was just...back in 3rd or 4th year, if I was back aged 20 or 21. It's only after coming back after several years of real-world problems that I might have realised that's a necessary part of the process. The reason I might feel like I will do very badly is based on my own experience with these puzzles of try and fail, try and fail, try and fail. Whereas I might not realise that I'm getting a bit better at it, getting a bit closer, but you can't know that without the benefit of hindsight, maybe 10 or 20 years down the road. That was just a process.

RESEARCHER: It was just interesting that some people, a minute after they worked out what to do, they had it solved, but it took them so much longer to get to that point than you. It was interesting looking at it.
P12: So, the hesitation was in a different point with other people.
RESEARCHER: If it was just...if the solution was to articulate what the problem was, you would have been in-and-out of here in 10 minutes, as opposed to some of the less experienced who took a while.

10. How did you feel about dealing with physical puzzles in a learning environment?
P12: Very interested. It was engaging, it was a lot of fun. As you say, with some people, some people had difficulty with different parts, and the process made that very clear to you as an observer, where people might have difficulties. It was different.

11. How did you feel about your performance with the puzzles?
P12: Average.
RESEARCHER: How did you feel?
P12: I don't really mind. I wasn't mean specifically measured against anyone, so I wasn't competing with anyone, so doesn't really matter.
RESEARCHER: Ok. It did to quite a few people, especially the competition thing. It was like Top Gear, people wanted to know how well they did.
P12: See if you'd had that, I would have hated every second of it.
RESEARCHER: I would have thought that was a bit aggressive.

12. What would you have done differently?
P12: If I was given a separate set of similar puzzles?
RESEARCHER: Yeah.
P12: I mean, now that I know that vocalising the part of the problem, I'd get that in and out of the way first. I might encourage myself to break and try more things more.
RESEARCHER: That's what I wanted to say to you, but I thought I better let you off.
P12: It was all very well...it was big and intimidating and well put together. I know how much work goes into those kind of things, so you didn't want to...I'd say that might have something to do with, the people who were, who had K'Nex as a kid, they can see that and they say "oh, that it took a lot of effort", cos I remember trying to do that and failing, so I didn't want to be too aggressive with this thing. You have to be gentle with it.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P12: The clues, the openness of the puzzle is nice. For me especially, I enjoy being able to look at the problem, turn it over in my head, and then move on. Because a lot of problems, a lot of solutions become clearer when you look away and let it sift through in the back of your head. The clues were, they were good. I almost don't like them, because they feel like giving up, they feel like, almost self-defeating, they give you a sense of defeatism because you feel like "I shouldn't need these!", but you do and therefore I'm a failure.
RESEARCHER: You didn't have to access them.
P12: Yeah but I did. I took off all 3, at least the 2nd of two.
RESEARCHER: That's exactly what you did.

P12: That's like a replacement for a 2nd person, maybe the 2nd person offers that 1st clue and that provides that Eureka moment that you're looking for. Because when you're thinking through the problem, you hit those speed bumps, and those clues are a little ramp to get them over.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P12: Feels good. If you've ever...it's never a pleasant feeling to be railroaded down one path, one solution. It feels like you're given a sense of power over the situation, in which you've been thrown into with no foresight. So, given the opportunity to actually choose the order, it's a small element, a small little bit of control. It's yours and that definitely helps things. When you've take an exam, you're not told "do 1, do 2, do 3, do 4, do 5" You do get to choose 5 out of the 6 questions most of the time, and that's similar to real life.

RESEARCHER: Ramble away, that's good.

P12: I'm not good at rambling.

15. What was your favourite aspect of learning like this?

P12: I don't know...the whole process, start to finish. It challenges you and then doesn't give you a numerical score at the end. So, I liked those elements of it.

16. What was your least favourite aspect of learning like this?

P12: I also didn't like that it didn't give you a numerical score at the end. That's a complex one. The same way you can't give a movie "it's exactly 85% on Rotten Tomatoes" That is not a rating for emotional engagement, you can't put a number on that. But at the same time, we're in such a highly competitive place here, everyone's competing for grades, for attention. It takes a bit of work to work yourself out of that mind-set, which is good. Forget about the numerical thing...it would be nice if there was more than one solution, I only remember being able to take one specific solution, but then they're based on real life solutions, so that's kind of a non-issue.

RESEARCHER: There is more than...I came up with one that was physically easy to make, for each of the 3 puzzles, there are variants of it that are possible. But, one of them was surprising to me. In fact, for The Lift, the solution I came up with that seemed to be the most obvious, no one did. Every single person that solved it, did it the exact same way you did it, which never occurred to me for some reason.

P12: What was your solution?

RESEARCHER: I had a ...the bottom clue is a piece of string that's the exact right length, and it was basically a hook that goes over the car, and the other mechanism is disabled, and when the elevator's down far enough, it tugs on it and it flips up, releasing the car. It's the same idea just the mechanism is different. For some reason I thought that was more straightforward and easier to build.

P12: And the hook attaches to the car?

RESEARCHER: It's got a thing at the top...there's another piece with it...it swivels on it, so it's like a little hinge. It's just resting on the car, but the car leaning forward holds it in place and when the elevator gets down, it tugs on it and just lifts it up. It turns out, everyone else did it differently.

17. Did you learn anything useful to you? What?

P12: Apparently I'm quite good at vocalising the problem, and vocalising the solution.

RESEARCHER: Well, understanding the problem. I know because you said it out loud.

Clearly what you were saying was what you were thinking, and I know that you were correct. Almost instantly, you jumped over the...you're the fastest at successfully making the jump to the designerly way of thinking.
P12: But the practical aspect of it is...I still have much to learn there, of the actual doing of it, which I find in real life as well. My other module is Game Design, where we try to make a board game we have to make something fun, and I'm interested in the theory of it, I've read books about it, listened to talks about it. You could lecture about it, you could lecture about it all day and then it comes down to making that thing that's fun, and all of a sudden, I'm struggling. Very true, very telling.
RESEARCHER: It was interesting because you were horrifyingly fast, almost instant with all of them. "He'll be finished in 10 minutes!" and then...
P12: Nah...

18. Did you learn anything that was interesting to you, and not just useful to know? What?

P12: The specific solutions were very creative, and required a lot of lateral thoughts, so if I could somehow apply that to other projects in future, those would be the interesting things. Using that cart that flips over, that definitely has some real world applications, the toggle switch...I'm just trying to visualise the specifics, the one that pushes the bendy straw out. I'm still kind of angry about it because I didn't want to break the thing. I didn't want to break the stand but then it could have worked without it, if you just took out more of the grey sticks....
RESEARCHER: I was so frustrated on your behalf.
P12: It's just my own thing. I just didn't break it enough, which probably would have solved some of the other problems…
RESEARCHER: Actually one of the things "what was your favourite aspect of learning like this?" it didn't happen, but I didn't have a Top Gear scoreboard put in. Several people wanted that, they said they would have liked if there was one, and several people said they would have made it even worse.
P12: It's the competitive nature of it. A lot of people find self-worth in comparing themselves to others.
RESEARCHER: Several people volunteered purely because their mate, then they wanted to have a go. Then, they wanted to know how their friend did, specifically.
P12: That's fine, if you're comparing friends and it doesn't matter as much, because you've self-worth outside of this numerical thing, but when comparing yourself to strangers on a scale of where you are now on an average bell curve, no one wants to be told they're below average.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?

P12: Yes? Yeah, it would have helped if I had been...if it was in a lecture setup, I can imagine that there would be some kind of easy-to-digest note form of a lesson to learn...here's an example there was a problem, but it was reframed to this and all of a sudden the solution is obvious, because that's [what] a lot of design thinking and design rethinking is learning to ask the right question. And when you change the question, all of a sudden the answer is obvious. Instead of "how do I cover up these barrels?", it's "what physics are available that can make one bottle invisible?" or "what setting changes make...what changes from this position, to this position?" and then you follow up with "how can I use the change this position?" and "how can this change be used to cover one barrel?" and that would be...I imagine that's "design reframing". That's

“problem reframing”. It's a difficult skill, because there isn't any specific course dedicated to it, and it's something that I found much more experience in, in the real world than any academic environment really...going back to undergrads, it was just “here's a problem-remember solution-give solution”. The only...the one that has the most parallels would be Physics in the Leaving Cert, which I imagine has parallels Applied Maths, and I enjoyed that a lot. That’s kind of a written version of this. You’re given a problem, you know your formulas, and it gives a certain number of numbers. In this case, asking the right question would be “what equation do I have that has all of these + X?” and then I solve for X. What equation do I have all of these now I have X and also Y, and the question is asking for Z, and that’s essentially Physics Leaving Cert. If you learn to do that and all of a sudden the entire exam is easy. Trying to apply this into a practical sense of step by step by step seems to be...
RESEARCHER: It is interesting, because some designers seem to insist that it just comes out of nowhere, these solutions, when...
P12: That’s bullshit!
RESEARCHER: Yeah, it is pretty much.
P12: There's no such...especially with aesthetics and inspiration, there's no such thing. Design doesn't happen in a vacuum. It's all the product of your own inputs and how you process them. Which can lead to unique outputs, but there's nothing original.

20. Do you care?
P12: Yeah.
RESEARCHER: Why?
P12: Always has questions, always been learning...it's just boring otherwise. That was a line in...the one with Colin Firth...Colin Firth and Dame Judi Dench. “Do you know everything or nothing?” The obvious right answer is nothing, because you can’t...oh yeah, that was it…”if ignorance is like some exotic flower, if you touch it, it wilts and dies.” There’s some truth in it, but at the same time perceived knowledge is its own reward.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P12: What do you mean “design thinking”?
RESEARCHER: Well, that's such a general term…
P12: It’s really annoying.
RESEARCHER: It is, isn’t it? The idea that, as opposed to just Maths where it is Logic and problem solving, but the idea of just having lectures about how you should think as a designer, when to an extent, you enacted those very processes. With someone like you, who has had more-than-average experience, because I had some 1st Years have a go, but they've just had a couple months, and some of those were Maths modules, and the idea that they can have a go at enacting design, even though they don’t get much of the theory until later. So, that’s what this was meant to be about...
P12: I'm curious to see how they’ll do.
RESEARCHER: They...
P12: Like, would coming straight out of secondary school, when you’re that much younger, and you have that much more creative thought, cos I’m sure that a lot of my limitations have probably baked in from the experience I had when leaving and having to conform to whatever jobs in society, and I’m sure I picked up bad habits that were actively limiting me in those kind of senses. Maybe having more practice in this area is stopping other areas, I don’t know.

RESEARCHER: I understand what you mean. You might have more knowledge of the subject than most of the participants.
P12: That's not always a good thing.
RESEARCHER: It got reflected in the fact that you were solving things much quicker than everyone else. It was then just a case of realising the solution. All done?
P12: I feel like I didn't really answer that, I guess, in as general a term as you could say that, a lot of design thinking is also a logic-based thing of problem + process = solution. The only difference is how you think about it? So, in that sense, it's...yes, I guess? You ask all these questions, there's no right or wrong answer. I'd like a right answer. There's at least a best answer, and I'd like to know what that is.
RESEARCHER: It depends on people's position. Some of them have been [here] just a few months, some of your classmates have only been here a few months, because they had completely different careers before here. Some are 4th years, who have been doing this for 4 years like you, so they have a different understanding, but there is enough of what educational theorists call "scaffolding" built into this. That, if a person knows nothing about the design theory, they can still have a go, even if means they have to use more of the clues.

C3.13 P13 Transcript

P13: Single: DMD 1st Year

1. How long have you been studying design?
P13: I'm going into my second semester of it now, so I've been studying since September, so that's 5, 6 months.

2. What do you think defines a successful student?
P13: I think, not only does the student have to learn their own skills and apply them to their own things, they have to be doing things on the side is also a good thing, like now I have an interest in Live Coding, which is good.
RESEARCHER: You went to that thing [recent event held in CSIS]?
P13: I did yeah, that was good. Yeah and taking influences from graphic design to try and bring it into my own studies, I think that's what makes a good student, or makes a successful student.

3. What do you think defines a successful instructor?
P13: Clear instructions. I like demonstrations. When I see someone doing something I learn it quicker than if it was written down, or if...if someone showed me how to do something, or shows me how it works I'd be better off in the long run of things.

4. Why did you volunteer for this testing with me?
P13: I volunteered for this because I think it might be a nice little insight for what I might do when I reach my PhD level, and also I thought you could do with a hand, so I thought I'd give you a hand.
RESEARCHER: Interested in research?
P13: I am. Well, I haven't done extensive research on a lot of things myself, but…
RESEARCHER: You're in the right place so.
P13: Getting submerged in some sort of idea or something, I think.

5. How do you think the physical nature of the puzzles affected your reasoning?

P13: I think the fact that, on the table itself, there was a few experiments around the place, so I thought that was quite distracting, knowing that I had to flip on, go to this one, and there was a timer and stuff...

RESEARCHER: You didn't like the timer, no?

P13: No, not particularly. No...

RESEARCHER: Would you have been less distracted if there was 1 puzzle?

P13: Yeah if they were on different tables. It is a bit overwhelming when you're up there. There were all sorts of puzzles around. Maybe I'll start this one, do a little bit of this one...I think if there was a puzzle here [gestures at the table], I wouldn't be looking at this one [gestures at another table].

6. How do you think the physical nature of the puzzles affected your emotional engagement?

P13: It did, yeah. When I may be given a project where we'd be given a brief, and I'd be given time to think about...when I start reading a brief, I'd be formulated some sort of idea in my head already, but it is already made and it's there. So, I don't know, I sort of get the feeling when I was doing it, there was a certain, specific way of doing it. If I was doing a research project, working off a brief, I'd maybe add some more individuality and add some personality to it.

7. How did "Working Alone" affect your thinking?

P13: I think I was talking out loud cos...for some parts, because it's nice sometimes getting a bit of feedback. Working by yourself? I don't know I found it slightly more intimidating working by myself. A lot more responsibility for me.

8. How did "Working Alone" affect how you felt?

RESEARCHER: You said you found it intimidating. Why?

P13: Maybe just the fact I may be had feeling that I might not been studying design as long as it should be, and there would have been people coming up who would have done better, so that was a certain amount of pressure coming into it.

RESEARCHER: Self-imposed pressure?

P13: Yeah.

RESEARCHER: Cos I certainly not...there has been 2nd and 3rd and 4th Year and the postgraduates that are studying design. Yeah, I had them in...I wanted to see how people got on. You did this a while ago, and you had very little experience, you just had a term and nothing more.

P13: I felt let down by myself, I should've done better.

9. Would you have preferred "Working in Pairs"? Why?

P13: I think so yeah, it would have been a bit nicer in teams or pairs.

RESEARCHER: Why?

P13: I think when I work by myself, I might talk out loud...sometimes nice...if I come up with some idea in my head and say it, and they can come back "oh hang on, this might be worth doing"

[REFERRING TO VIDEO NOTES]

RESEARCHER: Just thinking of how you did. Ok, you didn't solve any of them, but only 2 people out of 31 solved all 3. It was far more common for someone to finish 1,

and not do the other 2. You were so close with all of them! You started with The Scarecrow. One thing that you did, it's not unusual, a few people did this…you were playing with the K'Nex. Quite expert with the K'Nex, would you say?
P13: Yeah.
RESEARCHER: Yeah. Several of the people that are quite expert with the K'Nex went for building complex shapes, basically because they can, when they weren't necessary. Most of the people who did puzzles knew what K'Nex was, but weren't particularly used to it. That was interesting. You built quite a few complex shapes. You moved to The Lamp after 15 minutes when one of your possible solutions for The Scarecrow was in motion, so it was good. Then you went straight back to The Scarecrow when it wasn't working. Then you looked the 1st clue. You didn't look at the clues until you'd had a proper go then the 2nd clue straight away, then the 3rd you straight away and then you are back to The Lift, sorry then you went to The Lift. You were making the lower trigger on The Lift higher. I put in a note criticising myself for helping slightly too much because I knew you were almost there. I should've reigned that in. Then you went back to The Scarecrow, and you start building an even more complex mechanism of moving parts, I was quite fascinated. You did do...you were thinking your hands, you were fiddling with the K'Nex the whole time, you were manipulating the string to see the carriage up and down, which is more efficient than letting the motor do it. But you repeatedly...you even mentioned you want to use magnets! You didn't have a go at The Lamp, but you have a proper go at The Lift. You were almost there; I have a note criticizing myself there. That was interesting about building the K'Nex shapes. What this was meant to be teaching was Problem Reframing which is again, the idea that you get a problem and if there's no need to reframe it, then great everyone gets home early. One of the examples often given in lecture is "it's John's birthday party, I go "let's give him the best party ever" If he loves parties, we're done. Let's say you're his best mate and you go "actually, he doesn't like parties at all, he likes go-karting and there's never anyone to go with" So you've reframed the problem by removing "party" as the thing. "If we all organise a big day, he'll be much happier". So that's reframing, if you like parties is not problem but if he doesn't like parties, there is. The opposite of that is fixation, where a designer creates a thing like "it has to be a party" and then is stuck with that and refuses to move off it. So, that's what this was meant to be teaching. Thinking of that...

10. How did you feel about dealing with physical puzzles in a learning environment?
P13: As it was there physically, and had a few other pieces...that's maybe why I felt inclined to use a few K'Nex pieces. As I was going along, I would almost test myself first. That was one of the reasons I didn't look at the clue straight away.
RESEARCHER: You didn't want to.
P13: It's not like I'd become fixated on it...
RESEARCHER: People use the word fixated in normal English, and it's usually a criticism, and it is in design too. For various reasons, your brain produced the idea that building a K'Nex structure was the way to go. Now, probably you can...one person built a simple K'Nex structure that kind of worked, but Blu-Tack would have done just as well. That's what Fixation is. You go "K'Nex structure", and now everything you do, no matter how clever everything you do from that step onwards is...cos it was really interesting watching you work, because the first idea isn't rock-solid, it almost means...it's like you're at a crossroads and you pick the wrong one, doesn't matter how fast you're running, in fact the faster you run, the further away you're going from where

you should have gone. So, it wasn't criticism, you did do that! Do you think me explaining fixation, or you doing that was better for you to learn? You weren't happy that you did it!
P13: Yeah, I'm really not sure how to answer that question.
RESEARCHER: I would have thought that it student doing it themselves and maybe messing up might be more informative than just telling them in the abstract. That's what I would have in mind if it was a module and not a research project.
P13: I think just the fact it was physically there, that's why I was more trying to use the K'Nex pieces. If maybe...if I did ask how it should be done or given a hint, I would have regretted saying it.
RESEARCHER: Do you think because you experienced fixation that makes you more aware of what it is?
P13: Yeah.
RESEARCHER: That's a loaded question. If I gave you instructions or a description of lift you probably would be able to build it. It was interesting for me and frustrating for me because you always almost there tripping yourself up.

11. How did you feel about your performance with the puzzles?
P13: I felt quite disappointed.
RESEARCHER: It was almost there.
P13: I wish I'd just...if I was to do it again, I would have looked at each one, and would've went for one...if I was to go again, I would take the 1st clue from each one, and weigh up the options...first maybe.
RESEARCHER: The time management was harsh on my part, because that's what I wanted. So, as it turns out, it went well because 2 out of 31 people solved all 3. That was it. There was a 2nd group that if they had another 20 minutes, would have gotten an extra one. But it was my decision, that I wanted you...not so much to be under pressure, but to not have all day. It would force you to think and to make decisions about...so now that you've had a go, your strategy would be different?
P13: Yeah.
RESEARCHER: The whole point of this is to see how it affected their emotional engagement. It seems, from what you were saying, that you cared about how well you did. Do you care about how well you do in Maths exams in the same way?
P13: I think it's more self-thing proving it to myself as well.
RESEARCHER: That's what I'm exploring. Several people weren't bitterly angry, but were a bit. They kept staring at the puzzles during the interview, cos they were reliving it, like a flashback.

12. What would you have done differently?
NO ANSWER

13. How did the choice element, the ability to direct your learning, affect your thinking?
RESEARCHER: Were you happy with that? Because it sounded like you weren't.
P13: Yeah. I reckon even if there was a direction to take around the table? I think maybe, because it was given freedom of picking whichever one I want, maybe that put even more pressure on me.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P13: Because there was clues, I thought there maybe…have only one direct answer...maybe...
RESEARCHER: You're lost in regret there.

15. What was your favourite aspect of learning like this?
P13: I kind of liked the comical side, I liked the scenarios, stuff like that. That was good.
RESEARCHER: The Batman one [The Scarecrow] was really fully fleshed out one. The others were a little dryer, but I wanted a mix. You liked that?
P13: Yeah, I liked the fact that they're not just random things, they are things of significance, the light box [The Dalén Light].

16. What was your least favourite aspect of learning like this?
P13: Probably the timer.
RESEARCHER: Did it affect you while the game was on?
P13: Just at the end, when I'm made aware of the time, just makes things...puts more pressure on the situation.

17. Did you learn anything useful to you? What?
P13: Yeah I think I did. Not just...from the puzzles. But, in general, the research projects itself, a small insight...yeah. I still don't know how they actually are done.
RESEARCHER: Yeah you were the only person is specifically said "don't tell me I've come back and have another go" People who didn't solve any or solved one were "tell me". I'm still not going to tell you. It was interesting about the magnets as well, that you wanted...you were coming up with such off the wall things. "Mmm, magnets would work"

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P13: Now that I...when I first did the puzzle, I didn't know anything that was behind them and now I know what was behind it, maybe the Fixation, it's definitely made me more aware of some of the things that designers could get stuck in, some of the things that will be good if you left out, things I could avoid in the future so I don't get fixated.
RESEARCHER: It's one of the worse things. It gets worse the better you get, as you get more confident in your opinion and the trap for getting fixated in bigger.
P13: You're your own critique.
RESEARCHER: And your biggest problem, some of the time.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P13: Oh yeah, yeah. The fact that I actually physically seen and had it here, it would have been a lot more involving of me if it was this [points at puzzles], rather than a puzzle on paper.
RESEARCHER: Cos you did do it for The Lift. You had a solution that was...you had reframed the problem. You were suggesting building up from the bottom, which meant you jumped over the logic problem of having the car go faster, sorry, the car go slower, the lift go faster. You did jump over that. You came up with a solution. Building up

from the bottom causes a specific problem, even though, in principle, it's a correct solution. It gets in the way of the lift coming the whole way down. But in principle, that's the type of thinking that's just a hair away from solving the problem for real. So, you did do it. Which is better than me telling, in a lot of ways.

20. Do you care?
P13: I do.
RESEARCHER: Why?
P13: Cos I want to use this when I go on and do my own projects. With this whole fixation thing, I know I mentioned it...
RESEARCHER: I can feel the anger! Because I've had several people stare, and they're just...upset with themselves, and it was usually fixation. A couple of people were almost all the way there, and for some reason, they just couldn't physically build what was almost in their head, but that was a separate issue. Actually, you would have no problem with that, cos you were so good at building stuff!
P13: Yeah.
RESEARCHER: Maybe if you've partnered with such a person, you would have been devastatingly quick, so that's an interesting thing.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P13: Yeah, I think so now, because when I did approach it, I was just looking at how I could maybe make some other weird K'Nex piece that maybe reaches off over it but I wasn't really thinking, so I wasn't really taking gravity or all these other factors into accounts where am I not have had to build these things.
RESEARCHER: It was a harsh lesson, but there you go.

C3.14 P14 Transcript

P14: Single: DMD 3rd Year

1. How long have you been studying design?
P14: So I'm in 3rd Year, almost 3 full years. Yeah, it's the only amount of time I've been studying design. I suppose before that the only creative outlook I had was in secondary school for 10 years, doing art and...I wouldn't even actually call Technical Drawing creative. Art, painting, stuff like that. That was the only creative expression I had.

2. What do you think defines a successful student?
P14: I suppose in terms of, in terms of academia, it's grades, QCA, that sort of thing. In terms of the students themselves, I think it's grades and...I suppose emotional and intellectual fulfilment that you get from the course. I mean, if your grades are middling but you're engaged with the content and engaged with the course itself and what you're doing, your skills will improve over time but not within the confines of a semester or within 4 or 3 years.

3. What do you think defines a successful instructor?

P14: Someone who has a good knowledge of the field, who has a clear idea of the structure that a student needs to have in order to get to the end goal, or the overall goal of the module or subject, and has an understanding of...how to control or how to manage different student's abilities and student's expectations and time management.

RESEARCHER: They're the boxes you want ticked.

P14: Yeah.

4. Why did you volunteer for this testing with me?

P14: I volunteered because you asked me, and also just out of interest, just to see what how projects are set up, how testing is done, and also to help you out.

5. How do you think the physical nature of the puzzles affected your reasoning?

P14: I think the tangibility factor is really important. I suppose the only thing that...I dunno if this question comes later, but the only thing that creates some level of...anxiety or non-enjoyment is the time factor. The physical nature of it is really good because you can stand there and you can walk around it, you can interact with it and you can engage with it an awful lot more. Whereas a design student should have the capability to visualise something, like a drawing into a 3D realm, if you didn't, it just takes that effort away immediately, and you can almost visualise what you want to do. The only thing about it was the mechanics of it. It's just the mechanics of it, the colours can be jarring, just the...nature of the Meccano, or whatever it is, you can see through it, nothing's solid, so it can be a little bit disorientation. But certainly it's positive, as opposed to just having...

RESEARCHER: Ok, let's say they were spray-painted black, or everything was black. Why do you think the see-through thing was disorientated?

P14: Because, I suppose the...it's very hard to distinguish what's interlinked with what...the only one I'm thinking of is this one here, that's nearest to us,

RESEARCHER: The Scarecrow/Batman?

P14: Batman & Scarecrow! The way I worked anyhow was that I needed to understand how the whole thing works before I even could engage with it.

RESEARCHER: I know what you mean, cos it does look intricate even though you do had one thing, the on/off switch...

P14: It was still the nature of it that...could just how my mind works...I find very hard to accept things; I need to figure out what's going. Certainly, the tangibility factor's really important. Being given to space to interact with it on a one-to-one basis, rather than staring twenty feet away from a blackboard and trying to figure it out internally.

RESEARCHER: Partially it's a kid's toy, the colours...they're colour coded in the sense that if there's an orange bar, then all the other orange bars are clones of it, and if it's a yellow bar, it's a different size. But it's still quite vivid and overwhelming.

6. How do you think the physical nature of the puzzles affected your emotional engagement?

RESEARCHER: You mentioned that your thinking was clouded by the fact that there was too much in front of you.

P14: I don't think affected it too much. I suppose...like emotional engagement would be enjoyment?

RESEARCHER: Well the reasoning would be your “cerebral engagement”, the fact...I was asking how it would be affecting it, but in this case, did it...you mentioned the fact that you could see all the inner workings...was distracting, but did it make any difference that it was physical puzzles you're having a go at, rather than understanding a concept...even though you were doing both.
P14: Yeah, I think the fact it was...I think you explained the fact that it was this classical design problem, represented in a...I was going to say “simple form”, there was nothing simple about the setup. The fact that you'd said that added to the emotional engagement more...and the physical nature of the muscles would have added to emotional engagement, rather than, say, reading a paragraph in a book and writing a 500-word answer.

7. How did “Working Alone” affect your thinking?
P14: In one sense, it helped in the early stages, that I could have an internal dialogue about what might go wrong, but when you come to a sticking point, you've no one to bounce your problem area off, so what is not an issue for someone else could be an issue for you, and if you articulate that issue, they could explain it. Whereas working in isolation just means you get bogged down in that problem, and you've no one to communicate it with.

8. How did “Working Alone” affect how you felt?
P14: You probably could communicate what you...
RESEARCHER: How did you feel?
P14: Feel a little bit isolated, a little bit isolated when you consider that you've a limited amount of time...with the time pressure, you could feel like this problem is slightly overwhelming, then you get bogged in it and you can't, you can't get out of it and then you feel pressure. So, yeah in that sense.

9. Would you have preferred “Working in Pairs”? Why?
P14: I think in a pair. Anything more than a pair in something like that and...I think one person can become dominant in that problem...
RESEARCHER: Would you have preferred to work in a pair?
P14: I would prefer to work in a pair, yeah. I didn't think I would at the time, but after doing the problem I think I would have preferred to.

[REFERRING TO VIDEO NOTES]
RESEARCHER: Just looking at some of the elements of how you did. You solved The Lift with no clues. Well done.
P14: Yes!!!!
RESEARCHER: You started with The Lamp. After 9 minutes, you took out the centre rod and had the thing turned on. Then for another 10 minutes, including looking at the 1st clue...you had The Lamp on after 10 minutes, you then have the 1st clue, which is the switch after another 4 ½. And then another 6...you got sick of it after another 6 minutes. After 20 minutes, you moved to The Lift.
P14: Was it that long?
RESEARCHER: Yeah, 15 [minutes] is exactly 1/3 of the time, so after 20, you were getting a bit stuck...even though you were doing lots of fiddling with your hands. For The Lift, it took you 60 seconds to say out loud what the solution, jumping over all the problems...10 minutes to always get it right, and another 8 minutes to actually get it done. So, then you had it done. That was pretty much on schedule. Then you move to

The Scarecrow after 40 minutes, then you looked at the 1st clue, then the 2nd clue...the slightly annoying thing might be that 2 minutes after looking at the 2nd clue for The Lamp, you said out loud what to do, and then you talked yourself out of it for the next 5 minutes, and then moved on to The Lift. You didn't have enough time for The Scarecrow, but you solved The Lift...you said what you needed to do with The Lamp. That's what happened there, I'm just reminding you. We'll get to those points in turn in a few minutes.

10. How did you feel about dealing with physical puzzles in a learning environment?

P14: You've no choice but to engage with the problem in the physical environment, whereas...that's what's done in Labs, but in the strictly teaching sense...

RESEARCHER: Well, often in Lab, you're taught how to do a thing, whereas in this case it was being taught how to think so, and you could have walked away. You didn't have to turn up for a Lab, if I was teaching this. How did you feel about it?

P14: It was something that I had never done before, and it was...I came out of it having really enjoyed it, and came out of it then thinking about the problems after I left. In that sense, in that sense, it's a really good thing I guess. Whereas in a Lab, you've been taught how to do a specific thing and you're more often than not following a list of instructions. So that information disappears out of your head after a while, if it's not practiced. Whereas, with this, it's working a different area of thinking, and it's just a lot more, a lot more enjoyable, a lot more...I don't want to use the word "engaging" again, but a lot more engaging.

11. How did you feel about your performance with the puzzles?

P14: Disappointed.

RESEARCHER: Only 2 out of 31 now solved all 3, and no pairs [did], and several didn't solve any. Your score of solving 1 and correctly reasoning the solution for another is perfectly good. But, how do you feel about <u>your</u> performance?

P14: I always thought that problem solving isn't a strong point of mine, even though I am kind of logical in the sense of needing to figure out how things work before I'd progress.

RESEARCHER: Well to an extent, logic is something that wouldn't be much use to you here. There's a particular type of logical called Abductive Logic, but, a machine, I would argue, couldn't have solved all, or any of them. It's the ability...it's not logic. It's not like that puzzle where the Farmer has a fox, a bag of grain, a chicken...that's a logic puzzle. This isn't.

P14: I suppose...performance wise…

RESEARCHER: Does finding out that what you did was perfectly normal...does that make any difference? Did you think you failed because you didn't get all three?

P14: I didn't think about my performance in relation to how somebody else might have done it, but maybe I might have. I was thinking about my time management, how I probably spent too much time on the first puzzle, The Lamp puzzle.

RESEARCHER: Did you want to solve all three?

P14: Yeah, I did. But, I'm very much of the...very much wired in the sense that I need to do one thing then do another thing, then do another thing. I'm not great at jumping from thing to thing, so in that sense, I was disappointed...the time management and...maybe not solving another one? Maybe not all three, but I would have liked to get the 2nd, especially when I was almost there.

RESEARCHER: For The Lamp, you said what to do. You just couldn't quite make it work.

12. What would you have done differently?

P14: I think the reason why...I spent so much time on the 1st one and then I got the 2nd one fairly quickly was that...by the time I went onto the 2nd one, I've gotten into the headspace of what the whole...of what I was supposed to be doing was, so I aligned to my thinking to what I needed to do, whereas in the 1st one, I was very much warming up, even though that in itself was just getting used to the actual materials.
RESEARCHER: Well, the practice go before it began?
P14: Yeah, that was the materials and how to manipulate it, but I just wasn't clued into that mode of thinking, whereas I probably had been with the 2nd one. I don't know what I would have done differently, in that sense...
RESEARCHER: The Lamp is by far the hardest.
P14: Yeah.
RESEARCHER: The success rates for that are way lower than the others.
P14: Maybe just restructured my time a little bit more, maybe spend a few minutes, like what they tell you in The Leaving Cert, read the paper for the first 5 minutes and get your bearings, get an understanding, rather than diving into one problem, getting stuck, getting a little bit rattled...
RESEARCHER: That's interesting, cos it's pretty much evenly divided between people picking one arbitrarily but staying with it...and half the people steadily read all three before touching anything. Just different ways.

13. How did the choice element, the ability to direct your learning, affect your thinking?

P14: It meant that I tried to figure out what might possibly be...I think, what I was thinking? I think my thinking was "get the hard one done first", but I can't really remember. I don't know why I would have started on The Lamp...It might have been just that it was nearest to me. Anyway, I suppose my thinking was that, I was given the freedom to go...I can chance my arm with this, if it doesn't work, I'll just move on to something else, if that doesn't work, I'll move on to something else and then come back. In that sense, it took the...it took a little bit of the time pressure off so that I could move on to something without...without having to finish one thing. If I had to finish one thing, I might not have gotten any done, before I could move on. The fact that you don't have to finish something to start another one means that you can, you can get your bearings a little bit quicker, and you can move around, and it just gives you a lot more freedom in your thinking, and in...probably aids your understanding a lot more as well.
RESEARCHER: How did the clues affect your thinking. knowing that they were there?
P14: Knowing that they were there meant that...you had a...almost like a couple of lives, like a couple of "get out of jail free" cards, but you...I suppose you didn't really know what clues were.
RESEARCHER: You are hesitant to use them. You did The Lift without using any, and you only looked at the 1st one for The Lamp.
P14: I only used the clues so that...the reason I didn't look at the clues immediately was that I wanted to challenge myself and see if I could get it without any assistance. And then only...I think I only...for The Scarecrow, I absolutely dived into the clues because I was under time pressure, and then the other one was...the only time I might use a clue is that if I felt I had an understanding of what the solution might be, or what the issue,

what the pinch point was, and I just needed I just needed either validation or I just needed something to clear my thinking a little bit.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P14: The choice element added to the ...took away an awful lot of pressure, I think. I know I keep saying pressure even though there's no pressure involved in it, but...

RESEARCHER: Well there was. There was a limit and I deliberately chose things...I was hoping to make sure that hardly anyone would solve all 3, so it would force you to decide how to strategize.

P14: I suppose pressure comes from the timing and internalized pressure, but...it took away some of the pressure, and it made the problems seem less serious. You can just engage with it, suss it out, and then if you are stuck there's something there. It makes it more, the problems more approachable.

15. What was your favourite aspect of learning like this?

P14: Being able to…

RESEARCHER: You did laugh a lot during the video, but I think that was nervous laughter.

P14: [laughs]

RESEARCHER: Like that.

P14: Yeah. You're...you're able to externalise any kind of thoughts that you're having around the problem and you can...you can...you can chat about things. It wasn't strictly bouncing ideas off you.

RESEARCHER: Which you would have liked to have done with a partner, as it turns out.

P14: Exactly. I wouldn't have been able to sit there and be absolutely silent for the 45 minutes, and just knock out the 3 problems. So, in that sense, being able to do that was really good.

16. What was your least favourite aspect of learning like this?

P14: Just the materials. That was my first...doing that problem was my first time using it.

RESEARCHER: Ever [picks up K'Nex practice piece]?

P14: Yeah it was. Straight away you think you have a handicap already, you know.

RESEARCHER: This is like a Police interview. For the record, Colin has indicated the practice K'Nex mechanism that was done just before the test began.

P14: In that sense, you're...do I need...even the dexterity of using it. It is quite strong and all that, but at the same time, the intricate parts, you're...like with The Lift, you're going "I'm going to break this!"

RESEARCHER: There is that. Having said that, there's been several people that are quite expert in it, clearly spent their whole childhoods...a lot of them were building complex structures that were unnecessary. There's been a pattern of that, that people who had this as a kid and are really sharp, without thinking started building things that there was no need to, and that got in the way. There is that,

P14: There's a flipside to it.

RESEARCHER: I suppose, being familiar with it, but not obsessed with it.

P14: Exactly.

17. Did you learn anything useful to you? What?
P14: Yeah, absolutely!
RESEARCHER: What?
P14: The whole “reframing a problem”. It's not something that was said explicitly in any of the...in any of the...I just need to think this over just in case it was. I don't think it was ever...
RESEARCHER: It is a difficult concept to explain it in any real way, without examples. And what you did was you did lived the examples, rather than being just told it.
P14: In that sense, you’re...you're realising that this area of “reframing a problem” can solve...a simple solution can solve a really complicated problem, or a simple adjustment can solve a really complicated problem. Rather than trying to redesign the wheel, you can...you can just make some slight adjustments and I just think that in a lot of the modules, through no fault of the instructors or the lectures, I think an awful lot of the modules, the design modules, we go in and it's probably, I can't speak for everyone for me but certainly for me, I feel like I have to go in and come up with this grandiose solution. Whereas, if you go in and take a problem...break it down to a problem, and use reframing the problem as a strategy as well, that you might come up with a solution that is, that’s glaringly obvious, probably...and you don't have to go through...or it could be just be another tool that you can employ to come up with a solution. But it's something that I don't even think about when I’m approaching design problems is “reframe the problem”, whereas now I probably will.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P14: Probably totally irrelevant, but even just the...the context, the history behind the problems was actually really interesting. What else? I think...found interesting...the whole approach...not something you do every day...it was really interesting to come in and tackle a problem in a new way.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P14: Yeah.

20. Do you care?
P14: Yeah. Absolutely!

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P14: I probably said that as well. It's probably something that you can...I think at this stage of our learning, everything, everything that's new, that we’re exposed to is adding to the whole experience and is adding to the whole area, so being exposed to like that, and framed in such a way that you did, it certainly does, yeah.

C3.15 P15 Transcript

P15: Pair (with P16): iMedia

1. How long have you been studying design?
P15: 4 years, going on 40. It feels that long.

2. What do you think defines a successful student?
P15: A successful student is dedicated to their course. Unlike most students that I see, they're out drinking five or six nights a week and don't turn up to class. So I think dedication is the one.

3. What do you think defines a successful instructor?
P15: Someone who's engaging with your students. Yourself would have been one, I think. We've had a few lecturers over the years who just didn't want to do anything with us. So I won't mention names, because you're recording. We're asked questions in class and they just told us "look at your notes" and that was it. We still didn't learn anything from it. I think a lot of us will let down over the years, to be honest. Someone who likes to engage with their students and help outside hours. Like, I know you're helping a few people with their FYPs at the moment. Which is great. That's one for me.

4. Why did you volunteer for this testing with me?
P15: That's probably one of the reasons, because you were always helpful to everyone. You were always available for a chat, where most people would just walk past you. Again, I won't mention names. I could but I won't.
RESEARCHER: I know you're dying to.

5. How do you think the physical nature of the puzzles affected your reasoning?
P15: The physical side of things, I like. I enjoy those kind of puzzles. How it affected my reasoning? I'm not really sure to be honest. I can't really answer it, to be honest.
RESEARCHER: OK.
P15: Those kind of things, I just like to dive in and mess around with it until I get an answer. It doesn't it affect me as such.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P15: Emotionally? I didn't think it did. I don't think of things like that to be honest. I just get stuck in and hope for the best.
RESEARCHER: Did you...you mentioned it a few seconds ago you liked the fact that it was in front of you, in your hands.
P15: Emotionally?
RESEARCHER: I'm not expecting you to start crying. Do you like working with your hands?
P15: Before I came to college, I was a painter and decorator. So I'm constantly with my hands. I don't think of the emotions, to be honest, if that makes any sense to you? I just do it.

[REFERRING TO VIDEO NOTES]

RESEARCHER: Just thinking about how you actually did. You completed 2 of them...
P15: Almost 3...
RESEARCHER: Yes! You weren't into the clues too much.
P15: That's what I'm saying, I just want to get stuck in and try and solve it myself. I'm stubborn like that, I suppose.
RESEARCHER: You started with The Lift, and you didn't look at any clues and you had it solved on schedule. Then you moved on to The Scarecrow, you looked at the 1st clue after a bit. But then, you solved it. And with your 10 minutes left, you rushed over to The Lamp.
P15: 10 minutes to do that?
RESEARCHER: Yeah. You had 10 minutes. You got the light to turn on. Then you looked at the last clue…
P15: No, I don't think we looked at the last clue.
RESEARCHER: Sorry you looked at the 2nd clue, which is about being flexible. Then you built it correctly, but...you put the support arms back on.
P15: We actually thought the whole piece had to be a full unit going back in.
RESEARCHER: That was an honourable success. Now, interestingly enough, a couple of minutes before you looked at the 2nd clue, Tiarna said it out loud. Yeah, I'll ask her about that but that was a really impressive showing. You did 2 of them and I'd say if you had another 2 minutes you would have done the 3rd one, because you had it built correctly but you put the supports back on.
P15: We were trying to put a piece in to push, which was the 3rd clue in the box.

7. How did "Working in Pairs" affect your thinking?
P15: I suppose working in pairs, we both had own view of how things should be done. And I'm still thinking in my head all the time how much I would have done on my own. Working in pairs? I like working with pairs, I like working in groups. Affect my thinking? As I said, when I see Tiarna doing something I think is wrong, I don't really want to say anything to her, I just want her to carry on and do it herself make sure that she's wrong, then say I'll say what I have to say.

8. How did "Working in Pairs" affect how you felt?
P15: Again, going back to that, I let Tiarna do what she wanted before I said anything. How did I affect how I felt? I'm kinda stubborn, I like to get my own way when I know it's right.
RESEARCHER: Even looking at how you did, you did talk to each other really well. Some of the other pairs not so much, but you were working as a team. I would have thought, better than lots.
P15: Tiarna and I, we'd never been in groups together in anything during the 4 years. I thought it was ok, to be honest.

9. Would you have preferred Working Alone? Why?
P15: No. Not with those kind of things. I would have given it a go first. If I got another chance, probably not, no. It's nice to have somebody else there with their own thoughts.

9a. Were you comfortable with voicing your opinion?
P15: Yeah, yeah. Again, getting back to where I used to work, I used to run lots of jobs.

10. How did you feel about dealing with physical puzzles in a learning environment?
P15: I prefer that yeah.
RESEARCHER: Why?
P15: Because I'm more hands-on. I think I learn more from the physical side of things like that then I would reading a book. I hate reading books. I hate going to lectures, so it would take me longer to learn it, but I will get there eventually from the physical side of things, breaking it down, breaking it down breaking it down, putting it back together.
RESEARCHER: It didn't take that long, because it was timed to basically be the same length of time as a lecture...
P15: Was it 45 minutes?
RESEARCHER: It was 45 minutes. So, that's part of it...
P15: It actually went faster.
RESEARCHER: Most people were going "ohh!" [mimicking common reaction to time being up]
P15: I couldn't believe it was only 10 minutes left.
11. How did you feel about your performance with the puzzles?
P15: [expletive]
RESEARCHER: It was almost ideal. You were the closest to not solving the puzzles...of the people who didn't solve all 3, there was only 2 people who did all 3, you were the closest because you're a minute away.
P15: I actually thought I did ok. Tiarna was very good as well. As you said, we did work well together as a group. My own performance? Again, as I said to you, I'm stubborn. I don't like to look at clues.
RESEARCHER: That was interesting that you…
P15: I did not want to look at clues. I think it was Tiarna that actually said, at the 1st one [The Lift], "let's take a clue!"
RESEARCHER: At The Lift, you didn't want to look at the clues once you got into it. With The Scarecrow, she talked you into having a look at the clue.
P15: Yes, she talked me into it. I think it was the same with the light
RESEARCHER: And you didn't want you?
P15: No I'm stubborn like that. I'll keep going until I try and solve it myself.

12. What would you have done differently?
P15: No, probably not. I wouldn't have looked at any more clues. I would have kept going. If we had never 5 minutes, I would've solved that light one [The Lamp] eventually.
RESEARCHER: It was solved in your hands but then you added...
P15: Put it back together! I know we can't really ask you "do we have to have all back together?" It was up to ourselves.

13. How did the choice element, the ability to direct your learning, affect your thinking?
RESEARCHER: You started with The Lamp, fixed it…
P15: I think we started with The Lamp, then we left it and went to the next one.
RESEARCHER: No, as far as I know...
P15: Yeah, I thought we started with The Lamp and then we went to The Elevator. I think we did.
RESEARCHER: You started with The Lamp…
P15: Looked at the clues.

RESEARCHER: You didn't do anything and went straight on to The Lift. So actually, you had a choice in how you did stuff...then you had a choice of whether to access the clues, or not, as opposed to me giving you the clues if you got stuck. So, how did that affect your thinking, knowing that you could direct the way you were doing it?
P15: I could look at the clues, if I wanted?
RESEARCHER: Or you could move onto a puzzle without having completed one. How did that affect your thinking, as opposed to how you felt?
P15: It probably did affect my thinking, because looking at the next clue, I was still thinking of the one beforehand. It'd have probably been better if I was told to finish one, before I moved to the next one.
RESEARCHER: Would you have preferred that?
P15: Probably yeah, because in my mind, I'm always thinking of something else. When we got to The Lift, I was still thinking of the light [The Lamp]. As Tiarna was doing something, I was thinking with her on that piece, but I was still looking at the light, thinking "how can I fix that now?" Because I know my time is running out and I have to get to that.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P15: It was good to be able to choose.
RESEARCHER: Why?
P15: Because you could have spent 45 minutes trying to do one, and it would've been a waste of time. It was great to move on, but it did affect my thinking...I was thinking about the one previous all the time. Or even looking at the one ahead, I was looking both ways.

15. What was your favourite aspect of learning like this?
P15: It's more fun really, straight off the bat.
RESEARCHER: Why?
P15: It's something different, rather than staring at somebody talking crap for 45 minutes looking at a screen, you can get involved more. I think all lectures should be like that.

16. What was your least favourite aspect of learning like this?
P15: Amm…
RESEARCHER: Couple of people mentioned they hated the time pressure, it drove them mad. They would have preferred to stick at it, take as long as you want.
P15: That's kind of pointless, I think. You gave the same amount of time as a lecture, 45 minutes. Hate? I suppose knowing that the clues were there and I didn't want to look at them. That's probably one thing I didn't like. Will I, won't I? It's like playing a video game, if you take a clue, you're cheating.
RESEARCHER: Several people felt exactly like that, it's like giving in.
P15: Yeah giving in. That's exactly it. Like I said, I'm stubborn.

17. Did you learn anything useful to you? What?
P15: I don't think I can answer that question, to be honest. It was nice to work in a team.
RESEARCHER: You did do that particularly well. I think most of people who turned up in teams were friends. Not couples but they clearly are used to each other. But yours

was...standard in the good way, there's lots of talking, there was no ignoring each other business. That was really good.
P15: I'd like to say more that question but I can't.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P15: Again, that's a tough one to answer. I can say again "working in teams". You'll always learn something from somebody else. But, the actual puzzles themselves? It's all new to me so I couldn't really give you an answer.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P15: The reframing side of it? Yes.
RESEARCHER: Why?
P15: As you said, we talked beforehand, doing something, making it wrong, redo it again, redo it, redo it, redo it, redo it until you get it right. It's like you're in a lecture, you've a test, you're studying at home, you gonna keep at it until you get the right answer. That's really what we did.

20. Do you care?
P15: Yes, I do.
RESEARCHER: Why?
P15: It's always nice to learn something new. Before I came in, I didn't know that Batman was at the top of a hill with a couple of barrels. But, it's actually nice to learn different things like that.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P15: I'd like to say yes.
RESEARCHER: Are you going to say yes?
P15: So some aspects of it, yes.
RESEARCHER: What?
P15: Again, it's trying to figure out how things work, but probably a lot of the younger students would have used all these before. I never, ever used it.
RESEARCHER: I never used it before now.
P15: When I was younger it was LEGO.
RESEARCHER: Same.
P15: Did I learn anything from it? Yes, and no. Is that ok? I'm very bad for answering questions.
RESEARCHER: You're fine.
P15: But, I did enjoy it.

C3.16 P16 Transcript

P16: Pair (with P15): DMD 4th Year

1. How long have you been studying design?

P16: Been studying design since 2014, and so I'm in my 4th year of Digital Media Design. I overall think it's fun.

2. What do you think defines a successful student?

P16: In my opinion it's someone who puts themselves out there and doesn't put themselves in a box and get into this...get it into their head "oh, I can't do this, I won't be able to do this" It's someone that's open to trying new things, even if to do fail at it and...in the end, you're going to be successful one way or another in something. So that it be...for me I'd find myself...I'd be a successful student if I put myself in that mind-set, positive go for it mind-set and just see how it goes.

3. What do you think defines a successful instructor?

P16: Like a lecture or someone? Someone who is easy to talk to it and won't shut down ideas, or has one way of thinking and you're wrong. They'll listen to you and help you to a certain extent and basically someone that is approachable is really important. Yeah.

4. Why did you volunteer for this testing with me?

P16: When I heard...when you first asked people and it was put up on our group chat on Facebook, everyone, myself anyway were scrolling and had other things on our mind, and then I started talking to people that did it. Did it start in the summer? The end of the summer?

RESEARCHER: No it was December.

P16: Yeah, ok, wow, totally skewed there. They were saying how it was fun and in my head I was going in, I was reading it [my web page] thinking it's going to be something terrifying that I won't be able to do. As I said earlier, I shouldn't be doing that anyway. But then people were going "no, it's really fun, a proper puzzle and you get to do it!" So I said "sure I might as well give it a go" So that's why I decided to put myself forward for it.

5. How do you think the physical nature of the puzzles affected your reasoning?

P16: Originally when I came in, I was stuck in the thinking in my head "oh, what am I going to do?" and thinking-before-I-did-it-stage, but then when you were "no, go on. Go ahead and just change things and do it and just see what happens", when we did that I thought it worked way better. I found myself coming to terms with things quicker, and figuring out things quicker just because I could move them around and you weren't thinking "oh, you are not going to move this around because I'll break it!" because it was yours to do what you wanted with it. That's what I thought about that.

6. How do you think the physical nature of the puzzles affected your emotional engagement?

P16: I think I answered that in my last question really. Just being able to actually do it and not sit and stare at it and not put yourself into a rut made so much of a difference in my opinion, for me anyway.

7. How did "Working in Pairs" affect your thinking?

P16: At the start, I was worrying a bit...now I don't know if this is ageist, if that's even a thing, but he was older and maybe he...

RESEARCHER: Oh, it's a thing!

P16: Is it? He'll probably know way more and I'll probably just be standing here like an idiot not knowing what to do. But in the end, it worked out really well with Niall, because we both were actually on the same wavelength. When one of us wanted to move on, the other wanted to move on, which was really good, you won't get it all the time...why do I keep forgetting the question? [RESEARCHER repeats question]
P16: Sometimes I felt a bit, not afraid to speak up but that I wouldn't be heard, but overall it was positive.

8. How did "Working in Pairs" affect how you felt?
P16: I actually felt better about it because, me personally, if I was to come in to do this alone, I would have been totally overthinking it before I even came in altogether, but knowing that somebody was there, I felt way more confident and felt that I have somebody to fall back on really if I mess up, so that was it really.

9. Would you have preferred Working Alone? Why?
P16: I think I might have if the outcome was different, but after going through it with Niall, I think I liked working in pairs.
RESEARCHER: You did really well.
P16: Yeah it was positive and easy-going. We did talk through it, and so...

9a. Were you comfortable with voicing your opinion?
P16: At the start, I wasn't and then I started speaking up a bit more. I wasn't necessarily heard sometimes, not in an ignorant way, just because I literally...I was saying it out loud but to myself, instead of being "no, Niall, let's do this!" which if I had to do it again, I know now that I would do that and I would go and put myself forward and "stop being silly now, just say what you need to say, because everyone else is going to it" be a bit selfish in that way. Yeah I was then afterwards, I was comfortable enough voicing my opinion.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You read through The Lamp, you examined it then you went on to The Lift and you solved it all in the one go with no clues. Then you went on to The Scarecrow and looked at the 1st clue eventually, then...
P16: After a while...
RESEARCHER: About 5 minutes, and then you solved all of that, then you were back to The Lamp with 10 minutes to go...
P16: So, we had 10 minutes for The Lamp and we didn't it, did we? Nearly got it!
RESEARCHER: You built the correct solution, and then you put the supports back on when they weren't needed, and they blocked it. So you came as close as possible to solving all 3 as can, cos you actually had the 3rd one solved, and then you put the supports back on just before you put it down. If you had dropped the supports, and the person holding it put it down while waiting for you to pick them up off the ground, you would have solved it.
P16: It was that easy!
RESEARCHER: With The Lamp, before you looked at any of the clues, you said the solution out loud.
P16: Yeah, when you told me that, I was doubting myself straight away, like "no I didn't!"

RESEARCHER: You had 11 minutes when you moved to The Lamp, and after 7 of them, which means you had 4 minutes to go, before you looked at the clues you said it out loud, that "if we take the central one out!"
P16: That's what I meant by "I said it myself" instead of actually going for it and fixing it up and seeing what happens.
RESEARCHER: But then when you looked at the clue it basically...the clue was what you said out loud, so then you both agreed, and then you...
P16: A lamp went on! Excuse the pun.
RESEARCHER: You did really well. You were communicating out loud nicely with each other, you weren't bullying each other...
P16: Someone wasn't taking over; it was more a group.
RESEARCHER: It was a pity…
P16: I know! So close.

10. How did you feel about dealing with physical puzzles in a learning environment?
P16: I really like this because I'm more of a practical person anyway, like I'd enjoy Tutorials and Labs, being on the computer and doing stuff. Like for example, in SPSS we're working out things, so I really enjoyed the practical element of it, because me as a person, I've always been like that even as a child with puzzles...I'd love rather than reading books, I'd be up with my brother making puzzles. So, I just thought it made it easier in my head, when you see it to visualise it, it's just so much clearer and you can go ahead then and do it easier.

11. How did you feel about your performance with the puzzles?
P16: Good, but I didn't really feel good during it until afterwards when you said I actually said the thing out loud and for some reason that gave me a bit of confidence, even though it was a bit too late! Really, we worked through them well, we were so close to getting the last one, I'd say 30 more seconds and we might have got it, maybe a minute. But overall, great, I feel good about it.
RESEARCHER: Only 2 people did all 3, and you and another group, if you'd had another couple of minutes, you would have solved the 3rd one. So, it was really good.

12. What would you have done differently?
P16: Speak out louder, and actually go through with my ideas rather than just thinking about it, because I was thinking about it. I was saying it and I was going "maybe not" but I just went and did it, we might have got...as you said we'd 4 minutes left, we might have got further maybe.
RESEARCHER: Yeah there was basically a minute the half between you saying it and then opening the 2nd clue and then repeating it, so you would have had an extra minute.
P16: OK.
RESEARCHER: At worst.
P16: So I think...maybe I would have been less proud and opened another clue, for that one.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P16: It opened up...I felt way more at ease because I knew I had that choice, and if we were to start at The Lamp one, for example, and not know that we could have moved

on, maybe if we weren't told that and couldn't ask questions, we might have been at it longer and wasted time and not completed the other 2. Knowing that we could move on and we had a choice and it was free, it was really good. I think that impacted it really positively.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P16: Just good, positive!

15. What was your favourite aspect of learning like this?
P16: The fact that we did have a choice and it was open to us and we could do whatever and also the fact that we didn't feel like we were going to break something! We could just go ahead and take on...put on new stuff or take it off or connect things here and there. I really like that part of it because you just felt more at ease and when you're more at ease, you think clearer and can go ahead and fix things easier. I don't know what I'm saying, I'm sorry. I just got into this talking even forget what question is! Yeah basically it was the choice. Definitely.

16. What was your least favourite aspect of learning like this?
P16: The Lamp! No, I don't know...I don't think I had a least favourite, because it was really engaging and fun. So, I actually couldn't...I don't have any negatives about it.
RESEARCHER: The only real complaint has been "the time" that they would have...
P16: I didn't even think of that.
RESEARCHER: What did you think about the time limit?
P16: I think the time was fair and I think I'm being a bit...if we had a few more minutes, we've got that last one, so that's the way I am thinking about us. How long did we have?
RESEARCHER: 45 minutes.
P16: No, the time was fair.
RESEARCHER: It was deliberately timed like that, because...if it was maybe an hour, I'd say there with another 7 or 8 people that solved all 3. I was trying to make it to force you to choose, because you only had so much time, but you were…
P16: I liked the 45 minutes.
RESEARCHER: You were seconds away.
P16: I probably wouldn't like it if we had only had one of them done, so...
RESEARCHER: You would have liked it less then?
P16: Yeah!

17. Did you learn anything useful to you? What?
P16: I didn't realise how much...sorry now, I'll just word this properly...I didn't realise until afterwards how something practical could help me figure out things. The fact that that was practical [points at puzzles], I figured it out way easier than if I did have to sit back and think about it. If I answer a question on paper, I'd put myself in a rut personally, but the fact that I could get up and do it was way better.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P16: About myself, I learned that I need to stop putting myself down and being…and be more confident and just go for it, you're not to say wrong answers.

RESEARCHER: You did actually say the solution to all 3 really early, but I'm not counting the other 2 because you solved them.
P16: Exactly.
RESEARCHER: Just one last thing, about the clues. How did you feel about them specifically?
P16: I liked that they were there, but I also liked that me and Niall, as a team, we were trying to be proud and a bit cocky and not use them as much as we could, but we did obviously have to use them for 2, and...
RESEARCHER: But it was only 1 each! It was only 2 clues in total.
P16: Yeah, which I'm very proud of! And also, the fact that the ones we did use, we only did really want to do use 1. If we had to use 1 per puzzle, but the ones that we did use were the ones that we needed, they were exactly what we needed to know, so that was really good.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P16: Yes?
RESEARCHER: You don't have to say yes.
P16: I'm a bit confused, sorry.
RESEARCHER: [repeats question]
P16: What's Problem Reframing?
RESEARCHER: It's what you showed such a great ability for?
P16: Sorry...
RESEARCHER: It's when you simplify an argument. The initial condition is impossible, so a machine couldn't have solved any of those [points at puzzles] because it isn't logic. It's partially logic, but it's...you had to change and let go of something. It is the opposite of Fixation, when you're convinced it has to be this way. So what you did was you read the problems, and then you reframed them, make things simpler and worked out how the solutions worked. That's what it was in principle. Technically, it sounds like a loaded question, because the answer has to be "yes", but that's what it was meant to be teaching, instead of me giving a lecturer and saying what it is.
P16: No I think it did help, because exactly as you said, the fact that you could take it apart and work it whatever you wanted and make it simple and build it back up. That helped a lot for me anyway.

20. Do you care?
P16: No, I like that! In the moment I was "ok whatever" but when I went out and thought about it…it worked really well for me personally. I didn't know how much being practical would work for me in my head, and not being so flustered, like for example, I'm after flustering my way, made up a new word, through this whole interview. But when I actually get down and doing something, it was...it did actually help me understand it better.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P16: Let me think about this, for a second…
RESEARCHER: You were given 3 design problems and you pretty much solved all 3 of them...so you did actually do it, rather than listen to me telling you about it.

P16: Yeah...it did because...Design Thinking in my head has been very basic, so far. I haven't really...I know this is a design course and we've done Product Design, we've done things like that. But, I've never actually...I'm in 4th year now and that was something totally different and new. Rather than you having to sit down and think up things and go over it, which I know designers do, that's their job, but when you get to actually go and fix a problem…"I don't know what I'm saying, oh god no... I don't know if it's that I'm not understanding the question, why am I being so slow?"...I don't know, I'm just gone totally blank.
RESEARCHER: In essence, the question is meant to finish things "on an up", cos you did really well.
P16: Yeah.
RESEARCHER: If it was a lecture about Design Thinking, which I give to 1st Years, I'm talking and they're "ok I get the idea", whereas you actually...everyone's trying to do it, but in your case, you actually did really well because you completely solve 2 of them and you did solve the 3rd one, you just ruined it for yourselves by putting the supports that weren't needed back on. But if you'd had a couple of more minutes, you would've done it. You actually did really well.
P16: Yeah, ok. I just liked, as I said before, that it was practical. I also liked being in the group and doing it. And I liked that we had the choice element, because I think all those things made it really positive. When you have that in your head, and you're not under so much pressure, I just work better like that anyway, rather than sitting in a lecture and talking and just nothing really going in and having to go back then and re-study it yourself later. When you're actually doing it, I remember things better.
RESEARCHER: Can you remember what you did?
P16: I think I can, yeah.
RESEARCHER: You were getting flashbacks when I was reminding you!
P16: When I go up and look, yeah. I do, I do. Do I have to say them?
RESEARCHER: No, you don't.
P16: Yeah I do actually remember what we did. It was really fun. And I was trying to explain it to everyone afterwards...of course just went over their heads. I guess you just had to be there!

C3.17 P17 Transcript

P17: Pair (with P18): DMD 3rd Year

1. How long have you been studying design?
P17: 2 years.
RESEARCHER: 2 years?
P17: 2 ½.

2. What do you think defines a successful student?
P17: Some who is passionate.
RESEARCHER: About what?
P17: About whatever they're studying. Are you talking in particular about design, or just students in general? Someone is passionate about what they're studying someone who's driven, motivated...So, they've got their life fairly together. I mean, no one has their life fully together, do they, Researcher?
RESEARCHER: No.

3. What do you think defines a successful instructor?

P17: Someone who's able to plan things, communicate things effectively, someone who, again, is motivated, passionate. Passion is really important. If they don't have the passion...this is "User 15" talking... but like [Lecturer Name] who is teaching [Module Title] is brutal because she's absolutely no passion whatsoever! Loads of the lecturers we have are terrible because there's no excitement behind what they're talking about, but then you have the people who...like every module we've had with [Lecturer Name], we've all really enjoyed it because...they were enjoyable because she liked it and she was passionate about it. They were hard and she pushed us because she was passionate about it. Other people are just "you have to do this, do that" [Lecturer Name] is the worst, so annoying. They are bad things. Having passion is important, I think.

4. Why did you volunteer for this testing with me?

P17: Cos you're a friend of mine, I guess. We follow each other on Twitter...You're my 2nd favourite lecturer.

RESEARCHER: Am I your favourite one called Alan?

P17: Yeah.

5. How do you think the physical nature of the puzzles affected your reasoning?

P17: I don't think it affected it at all.

RESEARCHER: Really? Would you be the same if I had presented these as puzzles where I said what the puzzle, maybe did a couple of drawings on the board?

P17: No, I think I would have preferred just seeing it as it was, making my own interpretation. Are you saying you would have taught me what they were before I...?

RESEARCHER: Let's say if I gave you the puzzles in a lecture-type format where I describe what the problem was, and you had to sit there and work it out in your head, as opposed to playing with the pieces.

P17: It was more fun to do it that way, I guess. Is it a Design Game?

RESEARCHER: No.

P17: It was more fun to do it that way.

RESEARCHER: You don't have to say anything other than your actual opinion. I was just wondering if it affected the way you were thinking about the puzzles, the fact that it was in front of you or does it make no difference to you?

P17: Are you asking me...is it better for me to do the puzzle or for you to tell me about how to do the puzzle?

RESEARCHER: Not better...is it different to you?

P17: Yeah, oh yeah.

RESEARCHER: How?

P17: Doing anything is different to just having someone tell you about how to do something.

RESEARCHER: Why?

P17: Is that what you're asking? Because you don't get so much more from actually experiencing things to...it's like somebody told you how to cook a roast chicken, they might tell you how to cook a roast chicken, but if you cook a roast chicken then you know, cos everything's different, all these different things affect the outcome. What's your oven like? How do you like your chicken? You could follow the recipe but you're gonna change it, you might want more salt, or more lemon, or a little bit more garlic.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P17: Yeah.
RESEARCHER: Why?
P17: I just get bored when people talk. I'd rather do things, I'm a doer!
RESEARCHER: OK.
P17: Did I say something wrong? Do you want me to elaborate more?

[REFERRING TO VIDEO NOTES]
RESEARCHER: You were working in a pair with Carolyn.
P17: I think she hindered me.
RESEARCHER: We'll get to that in a moment. You read through The Scarecrow scenario and you began.
P17: The Scarecrow scenario?
RESEARCHER: The Batman thing. You did really well. You access the clues quite quickly. You several times did that without checking with her first, which is fine, I'm not criticizing.
P17: I'm independent. I'm a leader.
RESEARCHER: I'm reminding you of what happened.
P17: Yeah, I remember.
RESEARCHER: So, then you…
P17: Caz wouldn't know where the back of your hand was until you told her.
RESEARCHER: So you moved on to The Lamp, again...quite quickly figured out what was the problem, with The Scarecrow and The Lamp. Then...so you fully solved it, then went back to The Scarecrow. Then...
P17: The only reason we stopped with The Scarecrow one was because you had a technical difficulty with the thing [The Scarecrow: They broke it].
RESEARCHER: I did, yeah. I've written down that I repaired it…
P17: We would have finished that one first.
RESEARCHER: You went back to The Scarecrow. After 25 minutes, half-way through, you had everything solved, again it took you just a couple of minutes to articulate what the solution was, in principle...A contentious issue, yes. If you'd had 5 minutes...
P17: If I had another 40 seconds…
RESEARCHER: Tricky, yes.

7. How did "Working in Pairs" affect your thinking?
P17: Honestly I think it depends on who you're paired with. I think if me and Steve had been paired together, we'd have worked really well, because we work well together. But as Caz will tell you herself, I won't go in any groups with her. I can't bear...to work with her, we work completely differently, completely differently. Stephen, don't I say "Caz, we're not going in a group"
RESEARCHER: In general, let's say you're working with somebody you would work well with, how would it affect your thinking, as opposed to doing it on your own?
P17: I think working in groups is good in terms of...
RESEARCHER: What do you think?
P17: For me? Working in a group, for me, is good in some cases, because you get reassurance of what you doing, that what you're doing is right. Whereas if you're on your own, you have to self-motivate and make sure you doing everything right yourself.

But then you're also more driven to make sure it's definitely right, because if it's wrong, the blame is directly placed on you, rather than split between two people.

8. How did "Working in Pairs" affect how you felt?

P17: Being in pairs frustrated me because I'm usually the type of person who wants to get things my way, and I was fairly confident I knew the way how to do it, and the constant having to explain the other person's questions was frustrating for me.

RESEARCHER: Interestingly enough, Carolyn articulated, with words, the solution to The Scarecrow after 4 minutes, and she did the same with The Lamp after 2 minutes, and then did the same with The Lift after a couple more minutes. So I don't know if you were thinking the same things, but she was saying the solutions so fast. Were you listening to her?

P17: I was. I felt it was obvious what we had to do anyways from the clues and the task list. I felt it was obvious what we had to do for most of them, but...how to do them, she didn't understand.

RESEARCHER: Yeah.

P17: And I tried to explain how to do them, but I spent so much time trying to explain why I was doing the things I was doing...I think it slowed it down.

9. Would you have preferred Working Alone? Why?

P17: Yeah.

RESEARCHER: Why? You would just get things done?

P17: I think I would prefer to work alone in that situation. I would like to work with someone like Steve, someone I work well with for a situation...if I had to do it again...a similar type of thing.

9a. Were you comfortable with voicing your opinion?

P17: Oh, I'm very shy!

10. How did you feel about dealing with physical puzzles in a learning environment?

P17: I feel if this was a module, I'd want context about the topic, just a small bit of context beforehand, which I suppose, you gave us. But, not as much as I'd like, and then I'd like to have a go to puzzles. I never want you to show me the puzzles, how the puzzles are carried out. I'd want to do that myself. But then after, you can tell us, put it in context for us again.

11. How did you feel about your performance with the puzzles?

P17: Hindered by my partner with, but satisfied enough.

RESEARCHER: The only error you made at all, in any of them, was the final puzzle, where you were using the thicker K'Nex pieces all the time, and they weren't going to work. So that's what kept catching the mechanism. But you did so well, that if, for example, you accidentally picked up a thinner K'Nex piece, you would be finished in half an hour, because you knew how to do, you were saying it out loud.

P17: I think I said near the end though that it didn't matter about the weight of it was, the weight of the piece. I don't know if you wrote it down, but I think I said that at the end, that it was too heavy to flick off.

RESEARCHER: Yeah, you just needed a tiny bit more time. Actually, it was interesting...Carolyn got confused over the presence of a wheel in the box of parts, as in got fixated on whether the wheel should be part of it. Interesting.

12. What would you have done differently?
P17: I think the fact that you're with a partner or not affects that, because...I don't think anything I did, I would have done differently. Cos...I figured out eventually.
RESEARCHER: You figured them out really, really quickly. It was just building the solutions, and you still nearly...
P17: I figured the solution at the end, but if you subtracted the time I spent explaining the solutions to the other ones, I'd have had time if I was on my own.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P17: I don't think...I suppose it gave me the freedom of being like "ok, we'll start with this one, and if we don't think this one's easy, we might move on to other ones. I always want to get the easy ones out of the way so we'll have the last thing, the hardest one left to the last so we can have the most time at that. But, you can't tell which one is going to be easier or not. That seemed to be easier [The Scarecrow], I don't know whether it's because it's the one you explained 1st, we expected that one to be the 1st one. Even though it wasn't numbered 1, number 2, number 3, you explained that one to us first.
RESEARCHER: Interesting.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P17: It give me freedom.
RESEARCHER: Did you like that?
P17: Yeah.
RESEARCHER: Why?
P17: I got to move around between the different ones and then the pieces that I used to fix one were subtracted from the pile of pieces left to use for the other ones. Which was useful because if the pieces were gone, there are probably...the ones left over were for the other ones, so it gives you less of an amount to...figure out from.
RESEARCHER: How did you feel about the clues?
P17: You did say...you did say...when I was doing one, can I take a part of off something else, and I think you said I could. Maybe I'm wrong. I think you said I could.
RESEARCHER: Well you also could have asked for any specific piece and I would have given them to you out of the stash.
P17: I'm assuming you're gonna give us definitely the pieces that…
RESEARCHER: I did.
P17: ....we need…
RESEARCHER: And then I threw in a pile of other stuff.
P17: ...and then extra stuff as well.
RESEARCHER: Like the wheel...How did you feel about the clues? You weren't sure about using them.
P17: Clues are clues.
RESEARCHER: Yeah, why...
P17: You never said we couldn't use them!
RESEARCHER: It was the opposite! You can do it whichever you want!
P17: You never said we couldn't use them!
RESEARCHER: You weren't bothered by using them? You didn't feel like it was giving it, or losing a life or anything?

P17: No. Unless it was expressed to me that it was...that would be an assumption...but it wasn't. It wasn't expressed to me that it wasn't, it was that way so...if you said to me "you'll lose a life", if you had said that to me, I would it be more conscious of it, but you didn't say that.
RESEARCHER: And you didn't care, you just said "the clues are there, I use them if I want"
P17: Well, you get things done quicker. Like doing a project...it's like having an open book exam and being like "will I use my book? Or do it from my mind?" Of course you're going to use the book.
RESEARCHER: You didn't feel like it was giving in or anything?
P17: No.

15. What was your favourite aspect of learning like this?
P17: It was interactive.
RESEARCHER: What do you mean?
P17: I got to...like kinetic learning.
RESEARCHER: You're happier with that?
P17: Yeah.
RESEARCHER: Even though...the purpose wasn't to make you more dexterous. It's like learning to swim in a swimming pool is a good idea, because the end result is you have to be able to swim. Whereas in this, it wasn't how to use K'Nex better. The fact that you were able to use your hands, even though the end result wasn't to make you better with K'Nex, you were still happier…
P17: Kinetic learning is what it is.
RESEARCHER: I know what it is. I'm referring to K'Nex.
P17: I thought you were getting them mixed up.
RESEARCHER: Yes...
P17: Yeah the goal isn't to get better at using K'Nex, I know that, but like the actual experiences of the doing practical things always...I always remember it better. I learn better from doing things practically.
RESEARCHER: Do you remember them better too?
P17: Yeah, I feel. Yeah, you would, because it's an experience rather than sitting there listening to someone else talk about an experience that you didn't have, whereas if you experience it yourself, you're like....
RESEARCHER: I understand what you're saying, I'm just trying to get you to elaborate.
P17: Like if someone told you what it's like to feels like driving a car, versus if you actually drove a car yourself.
RESEARCHER: OK.

16. What was your least favourite aspect of learning like this?
P17: Working in a pair.
RESEARCHER: And you think it's not just…
P17: And also the fact that some of your...set-ups were a bit faulty.
RESEARCHER: Well, they weren't indestructible.
P17: I afraid they were, Yeah, I break things.
RESEARCHER: I picked up on that.
P17: Yeah. I break hearts, Researcher.
RESEARCHER: I heard that too.

17. Did you learn anything useful to you? What?
P17: Nothing new, particularly for me as a designer.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P17: Well, to be honest, I wouldn't say I've learned it because you told me the pretence behind those [points at K'Nex].
RESEARCHER: And you're perfectly happy with problem reframing? You knew how all that worked, did you?
P17: You told me what they were created for. I kind of remember. Don't properly know, so didn't learn it because you told me about it.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
RESEARCHER: To someone who fully understands how problem reframing works, you could answer "no".
P17: I don't think that you...I suppose that's one thing of not having something on paper and going back and looking at it after, and this obviously wasn't a classroom setting, but like you get...let's say if this was a module called...what do you call it? "Problem Reframing" and I knew I was going into that module; I'd relate it back to that's what it is. But if someone else asked me a few months later "what's problem reframing?"...because we're having this conversation, I would remember it more, but if we never had this conversation, and someone asked me what problem reframing was, I wouldn't necessarily relate it back to this. I'd just call it something that I did with Researcher.
RESEARCHER: OK.
P17: Do you get what I'm saying?
RESEARCHER: Yes-ish.
P17: I feel like if you had constantly harped on about, if you...this is random, but if you emailed me and "I want you to take part..." subject "problem framing", and you came in and I came in, and you're like "this is a problem reframing task", and you came in and "can we talk about that problem reframing thing?"...just small things like that would help to cement it into my head, if that's what it was we were doing, cos right now, it's something I did to help Researcher with his PhD.

20. Do you care?
P17: Yeah!
RESEARCHER: I know that seems like a silly question, but some people aren't happy with their college experience and are sick of it. Why do you care?
P17: Why do I care? Because I always want to learn more.
RESEARCHER: That's good enough.
P17: Why wouldn't I care about learning? Especially when it's something I...if somebody was trying to show me how to play FIFA, I'd be like [snoring sounds]. This, I care about.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P17: A little bit.

RESEARCHER: Did you care about the… I was just thinking about the fact that you were so close to finishing it all 3, the fact that you were looking at the clues quite freely. Did you care about finishing them?
P17: Finishing the clues?
RESEARCHER: No, finishing all 3 of the puzzles?
P17: Yeah, I wanted to...
RESEARCHER: Why?
P17: I'm competitive.
RESEARCHER: Is that why? What if you were the only person doing them? Would you be competitive with yourself?
P17: Yeah.
RESEARCHER: Just wondering?
P17: What do you mean?
RESEARCHER: Some people…
P17: I want to succeed, so even...regardless of if no one else is doing what I'm doing, I still want to succeed. I want whatever I do, to do well in it.

C3.18 P18 Transcript

P18: Pair (with P17): DMD 3rd Year

1. How long have you been studying design?
P18: 3 years in college, then I suppose, 2 years before that with Art in the Leaving Cert. I would count Art as design, in certain areas.
RESEARCHER: A lot of designers, while they'll say "it's creative", it is for a purpose. Whereas Art is creative but it's...
P18: Everything I did in Art was for a purpose.
RESEARCHER: OK.
P18: That's how I could do my projects.
RESEARCHER: But isn't Art more about you, and Industrial Design is more than everyone else?
P18: Mmm...yeah but I used to do art as...for projects. I was always doing projects for other people. I was doing it.
RESEARCHER: Interesting finding out a bit about you.

2. What do you think defines a successful student?
P18: A successful student, I suppose, would have motivation, time-management, passionate about what they're learning, but still able to have fun. Not completely academic all the time, because then you just go mad. I think, personally.
3. What do you think defines a successful instructor?
P18: I think personally been able to understand the views of the students and not just pointing and doing exactly what they think is right, but understanding how the students feel at the same time, understanding that they may at times be struggling, have challenges depending on the amount of work that's done. For someone has been teaching the same thing over and over again for the last 5 years, to just be like "this is easy!" and then have a few students who just don't get it and just push them to the side instead of actually helping them, because they just can't get it. I don't think that's

personally right. I think every student should have an equal chance and an equal opportunity if you're putting in the work, and you know they're putting in the work.

4. Why did you volunteer for this testing with me?
P18: Because it's you…
RESEARCHER: Fair enough.
P18: But I also think, when you were showing us the experiment I thought it was really cool and I was curious to see how well I do at my intelligence level [LAUGHS]!

5. How do you think the physical nature of the puzzles affected your reasoning?
P18: 100%.
RESEARCHER: Why?
P18: I work better by figuring out things with my hands...practical. If you want to just show me a video of that, I would have to continuously look at it over and over and over again before it finally clicked. Instead of me just playing around with it and then figuring out what the problem is. I'd find it out quicker by messing with it then actually viewing something over and over again to get it, I think. Is that what the question means? Is that what the question is on about? [*reads question again*] Yeah, because it's...especially with the 1st one, I wouldn't have understood...
RESEARCHER: Which one's that, The Scarecrow or...?
P18: The Scarecrow! I wouldn't have understood that the barrels rolled, unless I'd seen it moving. But if we weren't allowed to move it, then that wouldn't be physical.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P18: Mmm…
RESEARCHER: Do you like puzzles?
P18: I used to like puzzles, but I get very bored very quickly. That's my problem. I can't just sit there for an hour just being like all "which piece goes here?" like that just...my brain wanders too, too quickly. But I think because this was under a time limit, that made my brain going to auto-drives and wanted me to do it. I think if I was put...with the emotional, it stressed me out just due to the fact that I was with somebody else in it. If my source of reasoning wasn't the same as them, is my opinion wrong? What way does it work?

[REFERRING TO VIDEO NOTES]
RESEARCHER: You read through the Scarecrow scenario, and began. You actually articulated the solution after 4 minutes, which is really, really fast. Then you looked at some clues. All 3 of them actually, were looked at within a minute, and then you worked out exactly what to do and...Kate did that without asking you.
P18: Kate did all of that without asking me, but that's just the way Kate is.
RESEARCHER: OK. So then you solved The Scarecrow. You did go to The Lamp for a few seconds while I was fixing it, but you were back quite quickly. Then you finished The Scarecrow, using up about half your time. Then you solved The Lamp...really good. Again Kate looked at the clues without permission. You...after 4 minutes you said the solution out loud, then you moved to The Lamp...
P18: But then we didn't actually do it.
RESEARCHER: But then you actually said the solution out loud...after a couple of minutes, after 2 minutes, you said the solution out loud.

P18: And? Is that good or bad? I don't know.
RESEARCHER: That's really, really fast. Except for...you didn't act on it either time.
P18: That's because Kate is so forceful. Anything I say, I can't do.
RESEARCHER: You were really...going by other people's performances, like lightning! It took you 4 minutes to say what the solution to The Scarecrow was out loud, and that was before the clues. And then you said it exactly after you looked at the clues, in detail. Then, you moved to The Lamp while I was fixing The Scarecrow. It took you 2 minutes to say what the solution was. Then it took you 10 minutes to solve it. You go back to The Scarecrow, you solve that. So actually, you're only halfway through the time and you had both of them solved. Very impressive, you were really fast. Then, you went to The Lift and...
P18: Then we fell.
RESEARCHER: Well actually, you said with the solution was after 5 minutes. So you had 15 minutes...
P18: Just to make it work!
RESEARCHER: Yeah. You started using thicker pieces and you stuck with them, and that was the problem. Because it won't work, I have everything measured, so that with the thicker ones, it will be too strong and will push The Lift. You both got annoyed when you were running out of time. You kept getting annoyed when she kept opening clues without asking you, even though I said not to...
P18: Did you record all of that, is it all recorded?
RESEARCHER: Yeah, it's all recorded. There were 4 cameras.
P18: I know that, but I didn't that would be big information to jot down.
RESEARCHER: But that's not even a proper analysis of the video, just enough to remind you of it.

7. How did "Working in Pairs" affect your thinking?

P18: Well because it was Kate, anything she says has to go! I can say in my opinion I think if I done this by myself I would have thought about it longer, but not acted as quickly on it.
RESEARCHER: You will probably the fastest out of everybody with working out what to do.
P18: I would have played with all of them first. If I had done it by myself, I would have played with all of them first to come to a conclusion, and then went and solved them. But with Kate, she wanted to open the clues.
RESEARCHER: And you didn't?
P18: I didn't want to open the clues.
RESEARCHER: Interesting. We'll get to that again.

8. How did "Working in Pairs" affect how you felt?

P18: Forced! Pushed to the side, Researcher.
RESEARCHER: Can you think of anyone else that if, a specific person, that if you'd worked with them, it would have been different?
P18: Oh, Steve!
RESEARCHER: If you'd been with Steve, what would have happened?
P18: Well, Steve wouldn't have been as forceful with pushing. Because with Kate, any answer I say is wrong, unless it's proved right and then she can't say it's wrong because it's proved right. But Steve would take my opinion into account, and then we work in it together. Kate just went...she should have done it by herself, I think.

9. Would you have preferred Working Alone? Why?

P18: Yeah. I think I would have preferred anyone but Kate!

RESEARCHER: Let's say you had a choice between working with Steve or working on your own. Which one of those would you prefer?

P18: Walking into the experiment and not seeing...what the experiment was beforehand, [which is] what actually happened. I would have been apprehensive going in and doing it myself. I would have been a bit nervous and probably put more pressure on myself, but because there's somebody else there, I probably wouldn't have felt as nervous.

RESEARCHER: Yeah, it is easier...

P18: It's daunting to do it by yourself.

RESEARCHER: I did a thing today with statistics before this interview. 5 out of 31 didn't solve any, but they were all Singles. No pairs...every pair solved at least 1.

P18: Ok.

RESEARCHER: In fact, all the pairs except 1 solved 2. So it's definitely easier, because there is 2 of you working on it. You'd imagine that, but it turns out that's the case.

P18: If I had done it by myself and just got every single one of them right, would you have been like "she's a dark horse!"

RESEARCHER: I wouldn't have been surprised. You're the one who thinks you can't do stuff.

P18: Yeah. I get really put down by it.

9a. Were you comfortable with voicing your opinion?

P18: No.

RESEARCHER: Would you been if it was say Steve, for example?

P18: Yeah, well even at the same time, Steve would be like "mmm, I don't think that's right, but we'll do it anyway and try it" and then when it is right, it's "ok that's grand". Kate is like "no"

10. How did you feel about dealing with physical puzzles in a learning environment?

P18: Love it.

RESEARCHER: Why?

P18: It's practical, it gets you thinking. But you're not sitting there falling asleep either. I'd prefer every single one of our modules to be practical and physical. Like us doing things. Like Interactive Design Lab, post-its! That's how I learn. That's how I would learn. Either do things over and over and over again until I get it, or I do things that are interesting to me and that if I have an interest in it, it clicks straight away. Like those [points at puzzles] I know exactly how to make them now after doing it, because it made me think and I had the time to do it one time and now I know how to do it.

11. How did you feel about your performance with the puzzles?

P18: I was frustrated with the last one obviously [The Lift] because...I feel like the materials...if we had copped on to the materials quicker, because...we just used the clues more so than looking at the materials enough, and if we had looked at the materials quicker or realised that one is denser than the other, than...

RESEARCHER: Your pace that you did, not including The Lift, was great. You did so well, you were fine with the first 2 and you had the 3rd one figured out by 30 minutes so you'll a solid 15 minutes…

P18: Just to get it.

RESEARCHER: To do it. Then that became a problem. We can get into that in a bit...

12. What would you have done differently?
P18: I would have looked at the materials more.
RESEARCHER: Why would that have helped?
P18: Because then I would have known what was...the thicker ones that weren't going to work compared with the lighter ones and I should have made that connection, that maybe if it was a little bit lighter, it would help it slow down a bit more. But...I think it was due to the fact that I was with somebody else as well and obviously everyone wants to do...you want to work together on a solution instead of just voicing your opinion and just dictating how it goes. But that's kind of how it happened with Kate.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P18: I think the option to have the clues there was good, but if you were...I don't think…if you were going to do it completely, just trying to solve them under that time constraint, it wouldn't be possible. Well, maybe for some people...I don't think it would be possible without the clues or knowing what materials...even which direction you're going in to solve it.
RESEARCHER: That's what the clues tended to do, push you...
P18: The push in that direction. I think the time limit would have had to been longer if there was no clues involved.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P18: A bit more like I needed help.
RESEARCHER: Would you have preferred less choice?
P18: I would have preferred less choice, but longer time. But that's only because I don't like to take the easy route, myself.
RESEARCHER: How did you feel about the clues?
P18: Straightforward, really clear.
RESEARCHER: Not so much how they were written, but how did you feel about the idea of being able to access them, that you...
P18: I didn't want to access them!
RESEARCHER: I know, yeah.
P18: I didn't want to! I felt like the clues were the only option, if you had stood there and thought about it, but Kate went straight for the clues straight away and I didn't want...
RESEARCHER: Why didn't you look at them straight away?
P18: Because I wanted to figure out every possible way of doing it without looking at the clues first. And then if I could not think of any conclusion of how to do it, then look at the clues. That's the only way I would have looked at the clues, was if I'd played around with it and not known what the hell was going on and then I would have looked at the clues. But, sure look, Kate just went straight for it.

15. What was your favourite aspect of learning like this?
P18: Yeah! I love practicality! I love it! I love standing in front of something and solving it. That's how I work. I don't like reading a page of questions like this. It all goes like a blur. Talking? Perfect. That's how I learn. Communicating and doing practical things, 100% of the time. If I sit down to write an essay, it will take me hours. If I had a computer that was recording, synced up to my voice and I could just spill out

everything, then I'd be perfect. I'd find out way easier. Like reading assign...papers for like Mikael's thing [Module assignment]. Those as audiobooks? 100%. I'd know them straight off after an hour but because I...my brain...I can't focus for too long. I read a paragraph and then I'm "there's a cool print on that wall" like I just can't do it. That's just me learning.

16. What was your least favourite aspect of learning like this?
P18: Out of the experiments?
RESEARCHER: The whole thing.
P18: Time limit. I think...if it was an hour and it was no clues, I would have gotten them.
RESEARCHER: Oh you would have, easily...
P18: Because of the time constraint.
RESEARCHER: And you didn't like the fact that you didn't solve all of them?
P18: Yeah, that's annoying me. Yeah. But, we kind of did though.
RESEARCHER: No, you didn't.
P18: Well, as far as...
RESEARCHER: If you picked up, by accident, a slimmer K'Nex piece...you would have finished with about 10 minutes to spare.
P18: Do you think I would have done it by myself?
RESEARCHER: Yeah, because you did articulate the solutions so quickly, it was just a case of building…
P18: Did Kate?
P18: She can hear you, because you were saying words. She was saying them out loud as well, but it was usually after you. The only bit you got stuck on...you were the fastest to solve 2. Only 2 people solved all 3, and they were pushing the time. You could have easily been finished with 10 minutes to spare if you'd picked up a thinner piece. You get stuck on that.
P18: That frustrated me so much.
RESEARCHER: We'll have a question about Problem Reframing in a minute or two, but I would have said its opposite, its evil twin is Fixation, when you...Problem Reframing is when you simplify things, and you remove constraints that aren't actually necessary. Let's say it's someone's birthday and I say "let's give them a great party!" and if they like parties, there's no problem but if they don't then it is. You might know them better and say "no one ever wants to go paintballing with them, let's go paintballing!"
P18: Yeah, yeah.
RESEARCHER: But Fixation is the opposite. Fixation is when you add something, you create a constraint. So you did that with The Lift. You brought the bigger piece in and you stayed with it.
P18: Yeah!
RESEARCHER: It was working for the length, cos you were correct…
P18: But it wasn't working…
RESEARCHER: And it was strong enough to push the elevator into the sides, and you'll never get off that.
P18: We stayed fixed on it!

17. Did you learn anything useful to you? What?
P18: Don't work with Kate Torpey.
RESEARCHER: You're not the first person to say that.

P18: I learned that I'm actually not half-bad at puzzles.
RESEARCHER: You were very good.
P18: If I actually spent the time to think about them, cos usually most of the time I say...I do and say things before I actually think about it too much, and then I actually spent the time thinking about it...most of the way I speak with sound like I'm stupid all the time.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P18: I now know how to do K'Nex, and I appreciated Batman and Scarecrow were there, all LEGO.
RESEARCHER: A couple of LEGO bits, I did have to mix and match.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P18: What do you mean by Problem Reframing?
RESEARCHER: You had to reframe every one of those to have an attempt to solve them, so...it would be a concept that would be explained in lectures, but you had to actually do it.
P18: Yeah, I think that practically solving problems is probably easier than looking at a page and reading it and then trying to think about it, how to do it. Actually physically having it there and seeing it and playing with it and being allowed to do that makes it easier for your brain to comprehend.

20. Do you care?
P18: Depends on what I'm learning. Depends on what the interest is. If it's something that I have zero interest in and I don't think it's going to benefit me in any way, I just zone out.
RESEARCHER: What about this?
P18: I love that! That's design! I love solving things. I love having a problem. I don't like doing things with no benefit after. I don't...if I was designing something, I'd want an end-product. I don't like the fact of not having an end-product. Especially with like, the thing we're doing with Cristiano [current module] there is benefit there, we could be doing something good for the campus with the research that we do. So that's why I feel more passionate about it. When it comes to something like SolidWorks, we're making a stupid Stirling Engine that's been done every single year, just for the s**** and giggles, I don't appreciate it. In fairness though...if I...I said this when I had my grinds guy for SolidWorks, I said "if I had had the chance to play around with this in my own time, when I wasn't under a time constraint, and I wanted to do exactly what I wanted to do in SolidWorks, I'd love it. Like the Darth Vader egg cup. If I had that project, I'd be "that is sick" I'd love to do something like that, but it was so intense and doesn't isn't really required for the field we're going in the direction of, no. And there's a s*** teacher!

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P18: Yeah. It's only until after you've done the experiments that you can realise how you are as a designer. What you fixate on, those are the problem areas. So, if I…if I was going into something similar like that again, I would look at all possibilities instead of just looking at 1 and going with it.

RESEARCHER: Yeah, because you did the problem reframing for all 3 very quickly. You didn't do any fixation for the 2 you solved...that's why you got through it so quickly.
P18: Yeah. We didn't think about it.
RESEARCHER: You absolutely did for the 3rd one, and you'll never got off it. I'd say if you had another 20 minutes you wouldn't have solved it. You needed to accidentally pick up one of the narrow ones, and then you would have...but...I know...rage!
P18: I know.
RESEARCHER: OK.
P18: Make another one, and we'll do it just for fun!

C3.19 P19 Transcript

P19: Single: PDT 4th Year

1. How long have you been studying design?
P19: This is my 4th year in it.

2. What do you think defines a successful student?
P19: Design students, or just students in general?
RESEARCHER: Your opinion is what counts.
P19: Successful student? That they are willing to learn, and they want to learn. It is a bit of hard work and determination, but I don't think people have to kill themselves to be good students, or really, really work super hard. I do think, as a design student, I think it's really important that you can separate yourself from your work, because a lot of the time you have to be criticized and then to not be able to...to be able to take yourself out of that and then work creatively without the constraints of criticism or just all these things, cos that can stop you. That's for design students anyway, but in general it is about wanting to learn, to have a bit of a passion...putting the time into it, the good students do that.

3. What do you think defines a successful instructor?
P19: That they really understand what they're instructing about, when teaching the course.
RESEARCHER: That would be nice.
P19: Yeah. And also, that they really understand who they're instructing to, their level of knowledge beforehand, the best way of communicating with them. So, if they're young children, they use the best means to communicate with those children. Or if they're adults. I think there's quite a bit difference there. That they're conscious of, let's say in 1st Year, here in Product Design, our instructors are like "that's really bad, that's really bad!", when we obviously go in not having a clue about the course, I don't think that's good instructing. Because they're coming from a different place, then when in 4th Year, you can nearly take this because they're trying to criticize to help you, rather than criticise you. I think understanding the people they're instructing is really important.

4. Why did you volunteer for this testing with me?
P19: I thought the idea was really cool. Just when Aoife was talking about it and sent on the email. I read through it, and your [web] page was pretty professional as well.

RESEARCHER: It took me 5 minutes.
P19: I thought it was...it seemed really cool. And the challenge as well. You're like "that's intriguing, I wonder can I can do that?"

5. How do you think the physical nature of the puzzles affected your reasoning?
RESEARCHER: Do you think it did?
P19: Yeah, definitely.
RESEARCHER: Why?
P19: Because you can try it, and then fail and then try again, and then fail. It's through getting it wrong a few times that you know definitely "that's not going to work". If you're just thinking about it, and you're like "that'll work", but you never...a lot of people can never always see everything that can go wrong with it. So, I think definitely just trying it and being able to do it there was, it didn't waste that much time and you could just figure it out way quicker.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P19: Amm…
RESEARCHER: If I gave you a puzzle on the board, do you care more care, or care less, or is it irrelevant?
P19: I don't think so, I can't really…
RESEARCHER: No is fine!
P19: I'm just trying to think...you don't want to appear stupid, maybe. Because you actually have to move things when you have it physically, like you're "I don't want them to see me doing this cos I don't know if it's going to work out wrong or not"? But maybe when you're thinking it your head, you could eliminate that yourself without showing anybody, possibly. But, I didn't really see any big difference.

7. How did "Working Alone" affect your thinking?
P19: I'd say working in a pair would it make it easier.
RESEARCHER: Why?
P19: Throwing ideas off each other, and maybe that whole thing of "I want to be really smart and figure this out", but when you're working together with someone, you don't have that pressure on yourself, maybe…"this isn't showing how smart you are" Even though I tried not to be, I was like "oh, I need to get this, and if I don't I'm, you know, stupid." I didn't think "stupid", but that self-reflection when it's just you, but when you're working with someone else...I feel anyway that I'm taken out of that a bit and it's just figuring it out... and you've double the brain power as well, obviously!

8. How did "Working Alone" affect how you felt?
RESEARCHER: If you'd had someone with you, you would have been...if it was the right person…
P19: Yeah, with the right person.
RESEARCHER: You...would you be comfortable...you mentioned that if it's something in your head, then you can go through stuff, and while you have the disadvantage of not knowing a good one is right, if you think it's rubbish, no one needs to hear. Wouldn't that happen if you were working in a pair? That you'd be saying stuff that...?
P19: Yeah, true but you could just try it, and then prove it in a second that it's wrong.

RESEARCHER: You'd be OK with that?
P19: Yeah.

9. Would you have preferred "Working in Pairs"? Why?
P19: I think so, yeah.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You did really well. You were very close to doing all 3, except for a hint of Fixation on the last one. So, you started with The Scarecrow, you were quite comfortable with manipulating the carriage. You asked me questions before you touched anything, but you had a solution up and running on schedule, and then you moved onto The Lamp. You were about 7 minutes into that and you had The Lamp working. Then you accessed the 2nd clue and you immediately said...you know what to do now. It took you only a few minutes to get that together. Then you moved onto The Lift at 35 minutes. You tried to build from the bottom up, and that messed you up a bit, because that doesn't quite work. I thought you were going to solve all 3 because you had a solid 10 minutes left. It was interesting that you were comfortable with manipulating things.

10. How did you feel about dealing with physical puzzles in a learning environment?
P19: Yeah, it was interesting. I think...I wasn't really sure at the start, but I think this was me/myself, I wasn't really sure what I could and couldn't do. I didn't really know that I could take away that piece, even though you clearly said that I could do what I want with what's there. I will still "oh, I can't do that". So, that was interesting knowing that I stopped myself there.
RESEARCHER: It was difficult to read you, because you had two faces, one was really grim, and then one was this face.
P19: I think my thinking face is pretty grim, alright.
RESEARCHER: I didn't want to interrupt you either...you were just concentrating, ok...

11. How did you feel about your performance with the puzzles?
RESEARCHER: You did better than average, you solved 2 of them and except for a Fixation problem, that if you had, for some reason, picked lengthening the trigger first and not got stuck with heightening it, you would have done all 3.
P19: Yeah. I think with the last one [The Lift], I think I just didn't have enough time to...I thought I just said to stop that thing, put that thing down [Lift Barrier] and I just "oh, I didn't really have enough time" but I just kept trying to do it and even though "oh, I didn't have time" and I kind of gave up in my head before I actually finished it, so then when I was stuck on that, I didn't even think of...but I was happy with it, even the last one [The Lift], even though I did it the wrong way round, I kinda had the right idea nearly.
RESEARCHER: You did; you did the reframe thing. That solution has a specific problem; the lift can't get down because now there's a blockage. Whereas the reverse of it doesn't have that problem, but that was part of the design.

12. What would you have done differently?

P19: I would have tried more and done whatever and then if you went “maybe don't do that!”, I would have gone broader with what I was trying to do, rather than “oh, I'm not sure what I can do, so I’ll just do this”, because I was stopping myself in the certain bits.
RESEARCHER: You were a bit, but it didn't want to interrupt.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P19: By being given the choice?
RESEARCHER: As opposed to me telling you “you have to start with this one, and you can’t go off it until it’s solved”, or that you could look at the clues instead of them just being in the brief.
P19: Well, I think by reading all of them and choosing [The Scarecrow], because that was the first one I had an idea for, so then I just went with that one. I think you’re told to just do that one first [The Scarecrow], and you really haven't a clue about that one, then that would be more difficult in the whole process, you’d get more stuck, I think. And then having the clues as an option...I think it was good, because it was “oh, I’m challenging myself!” and you might try more things, go more outside the box, and you see the clue and you’re “oh!”...but it was really good to have them cos it could really direct you if you really got lost.
RESEARCHER: You looked at 8 out of the 9 of them, but the reason you didn't look at clue 3 for The Lamp, because you had it solved by then. You were quite free with the clues. You didn’t have any issue with accessing the clues?
P19: I think I wanted to try it first without them, but I knew I had a time constraint, and I'd rather a bit of direction, so I looked at them then.
RESEARCHER: You were more interested in making sure you solved them?
P19: Yeah.
RESEARCHER: Either way is a learning experience. Solving them it's good, but them out on your own is good too. You clearly have no issue with that.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P19: It was good, because then you felt a bit more secure, “ok, I'm not completely lost here”, I know how to approach it a little bit, by having the clues. It was a bit comforting.

15. What was your favourite aspect of learning like this?
P19: That you can just try it out, just try it out, like you think something and then you try it out. That it was a challenge, it not easy like, straight away you didn't figure it out. It’s a work in process, it was fun.
RESEARCHER: Do you think the trying out has to do with the way you’ve been trained?
P19: Yeah.
RESEARCHER: Well, you're guessing here, but if you're a 1st Year...were you always a “trying it out with your hands” type person, or...?
P19: Yeah, I think I was a bit, with some things anyway. Definitely, throughout the 3 or 4 years, it's always just...iterate, try everything out. I just know from building models,

I learned so much more, so much quicker than I would from sketching 10 pages. So, I just know that by trying out, you can eliminate it straight away, it's a lot quicker.

16. What was your least favourite aspect of learning like this?
P19: Just the whole thing of me not knowing what I could do. I felt like there was a lot of choice, to say the things that were there, like the Blu-Tack! Is that just there to trick me, or something? I don't know. That kind of...
RESEARCHER: Yeah some of it was. That's correct. I put in the bare things that you would need to do the simplest solutions, and I just threw a load of other stuff in there, but otherwise it would function is a clue, because it would be telling you what to do. So yeah, it was there to trick you.
P19: I think...it kind of "did what it says on the tin". Knowing that you were watching… "Oh, I'm going to try this but I have no clue if it's completely wrong!" Yeah, it wasn't bad or anything.

17. Did you learn anything useful to you? What?
P19: I think just go for it! Just try things out. It's not as if...if you got it wrong, it's not the end of the world. Just keep trying and you might get to the answer.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P19: The concepts were pretty clever, the puzzles...
RESEARCHER: Yeah, but they are representing really clever things that people did.
P19: Yeah.
RESEARCHER: But you did them! The Lamp, the thinking behind it won a Nobel Prize. It seems simple now, but wasn't then, and you basically replicated it. You did have a couple of clues to help you, but that's all.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P19: Yeah.
RESEARCHER: Why?
P19: Because you did really have to think about it completely differently. It's not just about going that straight line of like...with the last one [The Scarecrow], that it's not...say the story is they leave here, this happens, this happens, this happens, that you're not continuing on, your answer isn't carrying on the story, the start is actually...your answer is changing the start. So, it really is like taking completely...rethinking what we normally would do, it's the answer comes afterwards or something. It did, because you do have to think about. It's nearly like a riddle or something, it's completely...so it's not "it has to disappear", or "it has to fall out of the cart", it's just "hiding it".
RESEARCHER: And then you're ok.

20. Do you care?
P19: Yeah, it's always nice to learn something.
RESEARCHER: I know it seems an odd question, but...
P19: It's always nice to learn something and it's always interesting to reflect on it even now. You're asking the questions, "Oh, yeah it was like that, or this". Reflecting on it is kinda interesting.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
RESEARCHER: For example, Fixation is a problem that often gets worse when a designer gets better because they have more confidence in their own opinions. You suffered from it a smidge with The Lift cos you were saying that the time panicked you a little bit as well.
P19: I just think that I wouldn't have enough time to build whatever I needed, so I just kinda gave up. I was trying but then I was "sorry, I don't know"...I knew I had not that much time anyway, yeah. What was the question? Sorry.
RESEARCHER repeats question.
P19: Say in my FYP at the moment, I feel like I'm a bit fixated on something, so it's interesting now even trying to reframe it, because that's what I need to do right now, so yeah.

C3.20 P20 Transcript

P20: Single: DMD 2nd Year

1. How long have you been studying design?
P20: This is my, I was going to say 2nd year, but then I was thinking about it, I did 1 year in Limerick College of Further Education before I came here, so there was a design module in that, so this will be nearly my 3rd year.
RESEARCHER: What course was that?
P20: Level 5 Multimedia Design, so this is my 3rd year.
RESEARCHER: I did a year there before I came here as well. It was meant to be 2 years; a 2 year course...
P20: I could have done [Level] 6, but I said no…
RESEARCHER: I did the same.
P20: It was wonderful to actually, when the time the CAO came, saying "I'm going to do this now!" It was a leap.
RESEARCHER: It didn't really occur to me that I was going to do that.
P20: Yeah.

2. What do you think defines a successful student?
P20: When they get excited about what they're working on in their studies.
RESEARCHER: You talking about you as well? Does that make a big difference to you?
P20: Yeah...for me as well? I often stand back and say "Oh my god, look at how much I have learned!"
RESEARCHER: If you learned something, then that's good?
P20: Yeah, that's a good feeling.

3. What do you think defines a successful instructor?
P20: Successful in the eyes of the student?
RESEARCHER: In the literature, there's an interesting expression, "if there has been no learning, there has been no teaching" That if the students haven't learned something, then the instructor has made a complete mess!

P20: So, a successful teacher. Well sometimes I like when teachers...lecturers throw in something in a lecture about their own experience, how they made a step in their career by learning from somebody else or learning from a situation...I don't know...you're all such a diverse...
RESEARCHER: When you like the way it's been taught, if you've been...as a student, when do you...does the instructor have any impact on how you feel about it? I like this subject that is that, or does it affected by the instructor?
P20: Well there's workshops...it depends how the workshop has been facilitated. Does everyone in the class also engage?
RESEARCHER: I was going for your opinion, you can't possibly give a wrong answer, cos it's how you feel.
P20: Ok I'm coming blank. Might be better to go to the next one?

4. Why did you volunteer for this testing with me?
P20: Because I'm very curious about research, a kind of a selfish motivation.
RESEARCHER: If it had been some other...as in...it wasn't the puzzles or anything like that, you just went "research? That's interesting!" That was enough to get you hooked?
P20: Yeah. I want to learn more about research and the process of it.

5. How do you think the physical nature of the puzzles affected your reasoning?
P20: It makes me feel more in control, I suppose.
RESEARCHER: Why?
P20: It could be me working this out, as opposed to "here's an assignment, it's probably been tested already"...it'll be more immediate if you're in the room with it, working it out...I didn't realise it was also a learning thing, that I was going to learn from it.
RESEARCHER: How very sneaky of me.
P20: [laughs] It was like a task...I didn't know there was going to be a background and I was going to hear you tell about these people, these innovators who had worked with these scenario, these problems. And it wasn't until I got your follow-up email with the questions attached that I realised it...it didn't click that this was actually...when you solve...when you explore a problem trying to solve, that's actually design, I didn't know that until you wrote "Design Thinking" in your email.
RESEARCHER: In real life, let's say with The Lamp, that was a quest to have an automatic lighthouse, before they had electronics. So, they had gas and they had lights, but it would have to be a guy would come and turn the lighthouse on, and come back at dawn and turn it back off, to save gas cos it would have cost too much. The idea of having an automatic one, for us it seems simple, but it was before electronics, so he was using natural forces and he worked out how to get things to react to what was a uniform force. That's all they had...the whole point was it had to be automatic, but it had to be automatic in the way they wanted to be. Turn on at night and turn back off during the day. So that was a problem you had to solve. It took design thinking to work out how to do it. You have to replicate that in 15 minutes!

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P20: Yeah, you're exploring in a different way. I noticed now...we did a Lecture Tech, we were introduced to breadboards, I'd never done them before. So we got hands-on with them. And now this module...this semester, we have...we're revisiting it but only...but the lecturer has also given us a virtual breadboard thing, Tinkercad. So, I was

looking at that yesterday...it's not the same! [laughs] Because you first have to read the instructions that tells you what to do, before you get your mouse to put your...to move your wire into your breadboard in the right place. It's not the same as getting your red wire and counting the dots...the holes to get it in.
RESEARCHER: Which do you like better?
P20: Oh I like 3D world better!
RESEARCHER: The real world?
P20: Yeah.

7. How did "Working Alone" affect your thinking?
P20: I suppose it oscillated between... just saying "well, I can do this, just leave it to me", but if you have someone to reflect your..."will I do it this way?" it gives you more confidence, I think.
RESEARCHER: That if you had someone with you?
P20: Yeah.

8. How did "Working Alone" affect how you felt?
P20: It's kind of undistracted because you...it's only your own brain has to understand it. You know to "size it up", but then to make choices on what to do, you're kinda less reassured, I think. I think if I have someone and say "will I move it up here a bit and see what happens", someone else will say "oh yes, see what happens"

9. Would you have preferred "Working in Pairs"? Why?
P20: I don't know. It was a new experience, so I don't know.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You were very careful to read the instructions.
P20: Yeah.
RESEARCHER: That's not what everyone did. Some people glanced at them. I sure some didn't even finish reading them, and went straight into breaking things. So, you were very careful. Then, you were manipulating and playing with things...after a few minutes [She began with the Scarecrow], at 3 1/2 minutes, you moved to The Lamp, lots of twisting turning...obviously you can't pick the others up [The Scarecrow & The Lift] but you did pick up The Lamp, lots of this, lots of that [Researcher mimics manipulating The Lamp]. You solved that with no clues after about 20 minutes. Then moved on to The Lift, you didn't go back to The Scarecrow, you went on to The Lift, worked out what the problem was quite quickly, took you 10 minutes. Then you moved on to The Scarecrow after half an hour. Then you looked at your 1st clue, for the Scarecrow! Why did you do that? Cos you haven't looked at any of the 6 clues from the previous two puzzles...after 2 minutes...
P20: I thought that was the most challenging one.
RESEARCHER: You then solved it without looking at any other clues. It's just a reminder as well...
P20: I did remember a feeling of panic when you were giving me the instructions, cos...I tend...I tend to...I've a little voice in my head it says "you won't understand that!" I dunno...I've a little voice that says "you're dyslexic, you're a bit dyslexic, you won't be able to digest those instructions!"
RESEARCHER: You did comment on that. You did co-incidentally pick up the busiest one as regards instructions. Essentially, The Lamp is "do this and do that, The Lift is

do this"...The instructions for The Scarecrow are busy. It was an attempt to create a scenario, as opposed to the others which are simpler, just in case that would make a difference to students. But, you didn't like it, it was obvious you didn't like it.
P20: The instructions?
RESEARCHER: The instructions for The Scarecrow really busy, the other two are much lighter.
P20: It brought up a bit of...being a mature student among a class of mainly traditional entry, I have this thing of "they're all so quick on the uptake of things" I prepare myself a lot sometimes before going into class so that I don't...that I feel prepared in myself. But, I do have that comparison going on sometimes, a bit of an insecurity that these guys are a bit quicker on the uptake than me.
RESEARCHER: The only emotional response from you during the entire thing was lots of laughing when you solved The Lamp, like you were relieved or something. Your 1st one to solve.
P20: Yeah. I was a bit afraid that if I don't do this, I'm going to be stupid! But that's a personal thing...every student brings their own personal things into the classroom, I'm sure.
RESEARCHER: That's the problem with any theories like this, that they're generalities based on observation and everyone is different. So, you did really well. You're only the 2nd person out of 31 to solve all 3, so only two of you did it.
P20: Did you give the same background information to everyone?
RESEARCHER: Yeah. There was a sizeable amount that did 2, and got stuck on the 2rd one. On average, it's like solving 1 ½, so you actually did really well. And since we were discussing it a few moments ago, if you want to put it this way...you did better than almost everybody, cos there was only 2 of you that solved all 3...as a comparison.
P20: My antenna were really out to anything you were saying as well.
RESEARCHER: But, you still did it...just in time! But, that doesn't matter.

10. How did you feel about dealing with physical puzzles in a learning environment?

RESEARCHER: You're allowed to say you hated it...
P20: No, it would be good, because...having gone through it...now I can't remember everything, but...I would definitely say if you were to give me a paper on the people you mentioned, that would make it more interesting. Having done those things cos you would have your own reference to refer to, your own experience to refer to.
RESEARCHER: Do you like puzzles?
P20: Yeah.
RESEARCHER: I'm not mad into them myself, but several students have said that's what got them, word "puzzle" Suddenly, they were banging on the door "I want to have a go!" whereas some people, it was other things...they liked working with your hands
P20: I like working with my hands too.

11. How did you feel about your performance with the puzzles?

RESEARCHER: Considering in comparison to everyone else it was exceptional
P20: That has...that was nice. Well, first of all that it was "Design Thinking" and I had enjoyed it, and then I learned that it was "Design Thinking", it reaffirmed that...I tied it back to when I was in my 20s, I didn't finish the course I was doing then, but I got work...this is being a Prop Maker. You're always making things, and having to devise ways of making things. I did that for six or seven years and I said "I was doing designing

then!" So, this is what I got your email, so...I was talking to Roisín just a few weeks ago, saying...my daughter, if I could have seen a career path for myself then, because we were discussing what she might be doing after her thing...I would have, instead of leaving the course I was doing, I would have finished it and found a Masters in Design or something and that would have been a good...so now that I'm doing design and learning about it now, it's now...but I'm saying "I'm a bit ridiculous, I'm in my 50s doing it", but it's...
RESEARCHER: This question is difficult, because everyone else...even the last person I interviewed he was so fast once, he did 2...
P20: Just remind me of the question.
RESEARCHER: How did you feel about your performance?
P20: Well, if I did well, I'm good at design, so that's given me confidence that I'm studying design.
RESEARCHER: A guy yesterday, he did two of them so well, and he got stuck and you could feel the anger and the bitterness as he was staring the puzzles. He's still annoyed with himself a month later.
P20: Yeah.
RESEARCHER: Some people are just like that. At least he remembered what he did.

12. What would you have done differently?
P20: I would have...with The Lift thing...I wanted to find out about the length of the rope, before I started doing it. But you said something so I stopped myself. You said something, and I can't remember what it was, but before I did anything...after I done the Lamp, when I went around to The Lift, somewhere my mind I was thinking I should check the length of that bit of string cos maybe I could...but I didn't and then I...I took...I went at it from whatever the clues, not...the cues you were kinda giving, and...but at the end of it, you said had you tried the rope thing, it wouldn't have worked anyway. But I didn't find that bit out for myself.
RESEARCHER: That was bad on my part, giving you enough clues, because I'm trying to avoid clues.
P20: No, not clues...when I was saying my antenna was out, I knew there was going to be cues in something you were saying.
RESEARCHER: Oddly enough, my proposed solution for The Lift involved the rope, in a different way from what you were suggesting. Oddly enough, no one has replicated it. Everyone who solved it has done it in the exact same way, which wasn't something I originally considered. I had a solution where there was a hook that would go over the car and it's attached by a rope to the top of the elevator, and the elevator, when it gets to the bottom ends up pulling it up. To me that seemed the simplest way...but no one else it did. That question for the 29 people who didn't solve all 3, tended to revolve around the tactical error regarding the one that got away.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P20: Yeah that was good, because especially as there was a time limit on it, you had a choice of getting a bit of help. It took the pressure off, because pressure isn't great to work under either.
RESEARCHER: That was deliberate. As it turns out, I managed to judge it correctly. It was a bit of guesswork, but I did not want almost everybody solving them, all 3.
P20: Yeah.

RESEARCHER: Then, there would have been no time pressure. As it turns out, maybe it was a little strong because 2 solved all 3, but there was another 7 or 8 who were 5 minutes away. If I had made it 50 minutes, I definitely would have had 7 or 8 people solving all 3. But, there was time pressure. You were considering the clues to be "help if you needed them"? That's a very positive way of looking at them.
P20: It also meant they were solvable. If there were clues there, it was solvable.
RESEARCHER: I wouldn't do that to people!
P20: What?
RESEARCHER: I wouldn't do that to people, give them impossible...the initial state of all of them is that they're impossible, you have to change something. So you saw the clues as a help, a positive thing?
P20: Yeah.
RESEARCHER: Some people saw them as "I'm giving in!" a stubbornness about the way they were...they didn't want help. You were thinking...you find them reassuring knowing that they were there?
P20: Yeah.
RESEARCHER: You only ended up using 1/9 anyway.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P20: I thought that was very fair.

15. What was your favourite aspect of learning like this?
P20: I don't know...when you get the intention of the lecture. That you're focusing on your Design Thinking, your thinking process, so that...makes you feel that this is something important, that it's your ability. What did I like about it? The colours! The colourful setup!
RESEARCHER: Oddly enough, a couple of people found that distracting. One person said that the fact they could see the inner workings, they found it a bit of an overload, that they almost wanted to spend an hour examining how everything worked before they could move onto the puzzle. The colours are because essentially it's a kid's thing.
P20: It was a bit of novelty.
16. What was your least favourite aspect of learning like this?
P20: The instructions!
RESEARCHER: Because that's a personal thing with you, that you don't like...
P20: Yeah. Will I comprehend them? It's like anything...if I have to Google stuff on the Internet, I prefer watching a video and seeing how someone does it rather than reading "Adobe Illustrator: Follow the 5 steps how to do something!" for me.
RESEARCHER: By coincidence, you started with the worst one, comfortably. Then you stopped after five minutes and just you dropped it. You went straight onto the others then came back to it. So at least you didn't get thrown by that, too much.

17. Did you learn anything useful to you? What?
P20: That solving problems <u>is</u> design thinking.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P20: Well, what's very interesting just today is how precise testing has to be, just seeing your approach to this particular experiment, so I've learned a bit about that.

RESEARCHER: That was one of your intents in the first place that you really wanted to learn about research.
P20: So how you have to constrain the questions, it's just give me a broad...
RESEARCHER: You have to completely break it down, because otherwise, once there's three or four things in the mix, you don't know how they're interacting with each other, affecting everything. You just can't tell.
P20: Interesting.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P20: Even learning about there is this process called "reframing" and that's going to help... that's something to be done in order to design or solve problems. Yeah, it reinforces that.

20. Do you care?
P20: Oh yeah.
RESEARCHER: Why?
P20: Because it feels good to learn.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P20: Yes.
RESEARCHER: Why?
P20: Because of the stories of the 3 designers, innovators...just repeat the question?
RESEARCHER: Do you think that this experience helped you to more fully understand Design Thinking, in general?
P20: Oh yeah, I have a better understanding of the concept of design thinking.

C3.21 P21 Transcript

Participant 21: Single: DMD 3rd Year

1. How long have you been studying design?
P21: Almost 3 years.

2. What do you think defines a successful student?
P21: Successful as in "capable", or successful as in "good"?
RESEARCHER: What do you think?
P21: A successful student is somebody that can set a goal and generally attain it, work towards something, actually make it work. A good student might be diligent, might work hard, but a successful one is someone that can achieve what they set out to do, I think.

3. What do you think defines a successful instructor?
P21: Pretty much the same thing, just somebody that can instruct. Somebody who can instruct property, like what Kate was saying earlier, [Lecturer Name] she obviously I would say she does know her stuff, but because she can't communicate any of that properly, then it's pretty much useless to us. As an instructor, she's not the best and her inability to make yourself understood just means that she'd be better doing her job in a company or business somewhere, and not lecturing or trying to teach it.

4. Why did you volunteer for this testing with me?
P21: Because I heard there was puzzles and I like a challenge.

5. How do you think the physical nature of the puzzles affected your reasoning?
P21: Definitely I prefer being able to work with something in 3D and move it around. If I have to think about it, especially when you have it in your hands, it's so much easier to think "will this go in here? Will this happen? How will this work?", rather than having to go I see this drawing...you almost have to redraw it in your head as you would expect it to look. Actually having the physical thing in front of you was a lot better.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P21: Yeah, again just the fact that it was physical, it was like a challenge that was standing right in front of you. So it wasn't a theoretical one, it was practical you could work in it and see...every time you made another step forwards, you could tell that you were. Like when I was working on The Lift, each time I added another bit, to The Lift that I completed [laughs]. Each time I added another bit I could tell I was moving forward, another bit more, another bit more and then coming towards the end I was thinking "yeah that makes sense!" I knew that I was going to get it correct.
RESEARCHER: Do you like puzzles in general, or is it physical puzzles that you have a thing for?
P21: I like puzzles in general, definitely. Although, certain types I would prefer more than others. I'd like ones that aren't just really abstract and silly. Like, here's a puzzle but it's actually a play on words you have to pay attention to. They are kind of pointless.
RESEARCHER: Yeah, I know what you mean. They're several puzzles, when I started looking up these...Non-Insight Puzzles are logic ones, so it's like that one...the farmer has a bag of corn and a fox and a chicken. That's the type of puzzle that a machine can solve. Most of the Insight Puzzles were just stupid word games.
P21: Yeah!
RESEARCHER: 1 man marries 18 women, turns out he's a Pastor. I was trying to make Insight Puzzles that weren't stupid.

[REFERRING TO VIDEO NOTES]
RESEARCHER: One of the things you did with The Scarecrow carriage was you pulled it up on the tracks with the lead, which not everybody did. Several people did it but not everyone, but it's so much easier than trying to imagine. Is that what you meant by the physical thing, that instead of imagining what it would look like?
P21: You can picture it in your head, but you can't always have every variable happen in your head so if you pull it up "Will it be slow? Will it be fast? Will it rattle? Will things move?" When you do things physically, you can see everything that is happening as you do it. So you don't have to try and worry about what might happen.

7. How did "Working Alone" affect your thinking?
P21: I don't know. I think I might have done better, because I understood...I understood what you wanted from the puzzles, but what happened with the 1st one [The Scarecrow], I started thinking about like "how do I remove the barrel from the trailer and then put it back in?" and that's what I set my objective as, when it wasn't the objective at all.
RESEARCHER: You got stuck. The other two, you flew through.

P21: Because I understood what the objective, I was “this is what I have to do!” and even though you had it listed out perfectly, you were “make sure...make sure The Scarecrow doesn't see it” or something?
RESEARCHER: The Batman.
P21: That it can be seen by the time we get up there. And I just initially took that as it had to be made...not there for a while, so I just ended up overthinking it and then I couldn't stop overthinking it!
RESEARCHER: You started building what I would call an overly-complex K’Nex structure onto the carriage. You weren't the only person to do this. Most of the people doing that had experience with K'Nex, they had K'Nex for years as a kid, they liked it...you ended up doing something you didn't need to, even though you didn’t know it at the time. Why did you do that? Because you could?
P21: Yeah. Because, kind of because it was K'Nex. For the 1st challenge always, I was “here's K'Nex, here’s my building platform.” I wanted to use the K'Nex when I was creating the solution. Even though I saw the paper and everything else that was in the box, I wanted to build...every time I went for a solution that's to create a building, I want to build a solution that’s actually a contraption that’ll work in some way. Yeah, I just...that was kind of my thinking for that. I just wanted to build a contraption and that's immediately what my mind jumped to. When I got that final clue at the end, and I realised “I’m so stupid!” because it only took a second, immediately I saw that clue, I was “OK!”
RESEARCHER: That was at 43 minutes, so you only had 2 left!

8. How did “Working Alone” affect how you felt?
P21: Again, it might have helped, just have somebody say, maybe even just to pick up the paper and hold it in front of me, I’d say literally that would’ve just been like “oh wait, that's what I have to use!”, just for a second. Even if they didn't say anything else, and they just exited the room for the rest of the puzzles, I would have been fine. Just for a second they’ll get me outside the box.

9. Would you have preferred “Working in Pairs”? Why?
RESEARCHER: Now that you know how you went about everything. You did much better than average, you solved 2 and you would have got the 3rd one eventually. You definitely did the other 2.
P21: Maybe, but again it would have depended on the person a lot. Just anyone wouldn't have...I think like Kate was saying earlier, that we might have worked well together, but then often times when we both have opinions, we can be both a bit stubborn. Especially when it comes to a single puzzle, we can’t just work on it by ourselves for a bit and then come back and show each other what our ideas were, we’d both have to work on it...so if either of us went first, or either of us went with the other’s suggestion, we would have felt like we were wasting time if it wasn't the right one. I don't know, but then again Kate probably would’ve just suggested “what’s the paper for?” and then we would have definitely got through that puzzle quicker and the other puzzles would have been something similar, I imagine.

10. How did you feel about dealing with physical puzzles in a learning environment?

RESEARCHER: You said at some stage “we should be doing puzzles like this more often!”
P21: Oh yeah definitely, it’s just a really creative and fun way to learn. When you’re in secondary school and you’re sitting there and you’re looking at a book, you’re like “I just have to memorize this, this and this”, you're learning, but you're only learning it by heart. It means nothing to you, it’s just words that are going into your head. Whereas this is something physical, where you're understanding rather than learning. It's like when you finally get it to work, you understand fully how it works, because you made it work!
RESEARCHER: You took apart The Lamp mechanism…
P21: Exactly!
RESEARCHER: ...quite a lot. You got it back together! You ended up getting well into it, even with the...thinking with your hands, you were twisting and turning the mechanism. No imagination, you were just looking.
P21: When I studied Physics in secondary, a lot of it can be done practically, some of it can be, and the fact that it wasn't just made it so much more difficult to understand than if we been shown the experiments properly.
RESEARCHER: You mean like levers and things like that?
P21: Yeah, stuff like that.

11. How did you feel about your performance with the puzzles?
P21: Good, but a little annoyed. The 1st one was so simple, and the fact that it was so simple...if it was a contraction that I just hadn't thought of to make, then I would have been “ok, fair enough” It would have involved a little bit of work, and I just didn't happen to think of it. But it was so simple, that I literally “I just could have done that if I've had just a minute more and if I’d thought of it just a little bit earlier!”
12. What would you have done differently?
NO ANSWER.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P21: I really prefer that.
RESEARCHER: Why?
P21: In any kind of problem solving. Being able to move between puzzles, because if I feel like I'm getting stuck in a puzzle, or I'm like whatever...just not entirely sure of it, if I'm stuck on the puzzle and I can't move anywhere, then I have to stay working on it before I can get onto the next one. You saw the way, the fact I didn't complete the 1st one, which would have meant that before having to go onto 2 and 3, then I wouldn't have gotten any of them.

1**4. How did the choice element, the ability to direct your learning, affect how you felt?**
RESEARCHER: You didn't look at the clues for either of the 2 things you solved. Why was that?
P21: It's a challenge, it’s a puzzle. It kind of defeats the purpose if you’re taking out the answer as you're working on it. The challenge is there. And as you said yourself, it's solvable without the clues, so why bother with the clues? You know it kind of makes it less of a challenge, and at that point you could have just given a clue at the very end that would have pretty much given it to you, and all I would had to do was put in 1

piece, and then in that case it's not a challenge, it's not even a puzzle. It's pretty much back to rote learning.
RESEARCHER: Ok, so you were doing fine with your reasoning for the two that weren't The Scarecrow.
P21: Yeah.
RESEARCHER: So you didn't look at any of the puzzle clues. Everyone who hasn't solved The Lamp, once they see the 2nd clue, "That centre rod is so inflexible", then they go "oh, I get it now!" But you didn't need them, so you didn't look at them. That would have been giving in, would it? A little?
P21: It's not so much giving in, as...taking the fun out of it.
RESEARCHER: Fair enough.

15. What was your favourite aspect of learning like this?

P21: Probably the physicality and the challenge.
RESEARCHER: That there was a correct answer, and you had to get it right or not?
P21: Yeah, and it was up to us to be creative and figure out the answer. That it wasn't just like "here's 3 possible solutions. Which one is correct?" It was like "we're not giving you the answers, you just have to come up with them"
RESEARCHER: Because people came up with different solutions to the one I did. In fact, the 3rd clue for The Lift was what I thought was the most obvious way of doing it, but no one's done it. All the ones who solved it have pretty much done the same thing. The Lamp...a few people have done the exact thing, a few people made slightly complex structures but it amounted to the same thing. People have done wildly varying things for The Scarecrow, but the same idea in principle.

16. What was your least favourite aspect of learning like this?

P21: Probably just the way that I was thinking, again I'm jumping back to The Scarecrow a lot...the way...
RESEARCHER: I can taste the bitterness.
P21: It's just, when I started building first, and the reason I was going for such a complex thing was because I was thinking of it in as human terms as possible. So I was thinking at The Scarecrow as an intelligent person that could look at the trailer and be like "there's something obstructing this" or "there's something here!" and that's why I initially went with take the barrel out, so it's not something he could ever think "there's something hiding there" and then when I realised he said "hide", it doesn't have to be visible, it was just so much simpler.
RESEARCHER: If you would have solved out 3, would the answer to this question be "oh, it was fine!"?
P21: Yeah. I had fun.

17. Did you learn anything useful to you? What?

P21: Just not to constrain myself when I come to an idea, like with the other ones, The Elevator, I was talking to you as I was doing it, and I can see where I could make the changes. We know that the car moves at a certain speed, and that maybe I can slow it down somewhere, the elevator has to move as well. So I was looking at the different variables and where I could change them. That was the right way for me to think about it, as compared with the 1st one. Here's a solution that's in my head that I'm somehow going to try and make work, which it just wasn't going to.
RESEARCHER: The opposite of reframing. It's called Fixation, where you get stuck on something that you're saying this has to be the way it is.
P21: It has to be it!

RESEARCHER: At least you did it, which is not, not good. At least you know what it's like now. You didn't do it for the others, meaning you'd let go of the constraints and worked it out.

18. Did you learn anything that was interesting to you, and not just useful to know? What?

P21: That maybe I should be a little more willing to look at the hints as well? Just because for the first one...

RESEARCHER: Would you have preferred...I know you would have preferred to solve all 3 with no hints, that's obvious. But if it's a choice between nearly solving all 3 and not looking at hints, or looking at the hints for the last one and solving it, would you have been happier with that? Would solving them be more important to you than the hints?

P21: It's not so much succeeding, as it is "rising to the challenge" that's important to me. I can succeed if I just looked up the answers, I could just be like "ok, there's the solution", well I couldn't cos you invented it, but in everyday life there's probably an easy solution to most things but it doesn't necessarily mean it's going to be the fun one or the interesting one, or you're not going to benefit from it eventually. So, maybe using the hints more often would have been better, but even so I still wouldn't have used them that much at all, if it was an option.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?

P21: Definitely.

RESEARCHER: It's a loaded question. Why?

P21: Because you're involved in it. It's because you gave me that to solve, I could almost understand the way the guy was thinking as he built it. Because it was literally "how do I get the solution to this problem?" That was somewhat similar to question he was given, so when you're working on it, you're "how does this work? How does this work? How does this work? "and then by the end, you can look at the mechanism, and "what parts made sense?" You're teaching yourself, and then...if you had wanted to, you had the hints, you...in a teaching situation, you would have been the hints and you could have helped with some information, been like "here's how this works, here's how this works" and then we would have gotten the solution. I've been able to work there by myself really helped me understand it a little better.

20. Do you care?

P21: Yes.

RESEARCHER: Why?

P21: Because, it's like...literally if I'd gotten the last one, The Lift, or even the 2nd one [The Lamp] by accident, I would have I asked you if you could let me redo it again, because I would have <u>hated</u> the fact that I got it by accident, it's pointless. You getting the answer but you've no idea what it means. It's like somebody handing you the answers to a test. Grand, you got your marks or you got your % that you wanted, but you have no idea where it comes from, it means nothing to you. It's pointless.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?

RESEARCHER: It ended up being about Fixation, because of your skill with the K'Nex.

P21: Lack of!
RESEARCHER: It's not really possible to do with the K'Nex pieces, that part of the puzzle.
P21: Trying to Blu-Tack it to a wheel was a little bit excessive!
RESEARCHER: There is that, yeah. Do you think the experience helped you understand Design Thinking a bit better? You mentioned about the Formula 1 racer that you could...
P21: I would think so, yeah. Like I said before, it's putting you in the original designer's perspective. It helps you think the way they would, usually. Obviously not with the "Fixation" one, I just couldn't get out of my own head, but with all the rest of them you were still able to think basically the same way that they were, and think it through and get your solution.

C3.22 P22 Transcript

P22: Single: PDT 4th Year

1. How long have you been studying design?
P22: So I'm in my 4th year. So, that's 3 1/2 years now. Do you just mean in college?
RESEARCHER: Have you done design somewhere else?
P22: In Secondary School, I did Art and Technical Graphics, so I've kind of always had an interest in design, but it wasn't really until I got into 4th year in school I actually wanted to go down the design path, the creative path...I did a placement in an Architect's firm and I did like it, but the Architect side of it...maybe it was the office I was in but...it felt kind of...it wasn't a very fun environment, the Architects office that I was in, cos that's what I was thinking originally, it was Architecture, but then I kind of went down with design of everyday products.

2. What do you think defines a successful student?
P22: Obviously grades are hugely important but for our design, for product design, at the end of the day when you're going to look for jobs, they don't look at your QCA. They don't look if you got a 1:1, [or] if you got a 2:1, they look at your portfolio. So a good student, a good design student is one that would have a good portfolio at the end, one that they're happy that they can show it to future employers. That's what I think for Product Design anyway. For a general student, grades at the end of the day, but also that you're actually enjoying college as well, not literally at your wit's end every moment of the day.

3. What do you think defines a successful instructor?
P22: The grades that they're students get. If they are successful in what they're trying to teach them. That the students understand and are able to go away and actually do whatever they were taught themselves and do it successfully.

4. Why did you volunteer for this testing with me?
P22: Honestly because…
RESEARCHER: Aoife made you…
P22: Not made me! Informed me of what you were doing and I actually thought it was really interesting that you're looking into the way design is been taught because, for our

course anyway, were forever...not giving out about our Lecturers, but have complaints sometimes when they're doing some things or they don't tell us when certain deadlines are, stuff like that. Even the way they teach us sometimes. They give us one-day-mini-workshops on something, and then they expect you to be experts at the end. I don't know what exactly you're hoping to get at the end of this, but I think it's a really interesting area to understand and learn more about, and I think because designers sometimes aren't the best teachers. Like whatever they might do in their own careers they might be very successful but actually teaching someone is a lot different. I think it's a really good area as well...and Aoife slightly made me do it. [Laughs].

5. How do you think the physical nature of the puzzles affected your reasoning?
P22: I suppose that definitely made it more fun and it made it more interactive and it was easier to pick up stuff and look at stuff and see how it was all...what I do by touching, looking getting a 360, a 3D view of it rather than something on a page. Also it was fun to do as well.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P22: It didn't make me as frustrated, because sometimes when I look at something on a page, I get frustrated, "oh, I'm not really sure exactly what that is!", and here I was giving more to see, so it made it slightly easier. I was happy to do it. I was a little bit frustrated because some of them I just couldn't…"oh, where am I going to go with this?", but it definitely made it easier that it was something that you could do.

7. How did "Working Alone" affect your thinking?
P22: I know me anyway I find it easier working in a team, just throwing out ideas and getting ideas back from someone else. I do find that easier, so it was a little bit kind of challenging but...and I suppose I do like working it out someone else, but at the same time...I didn't really mind doing it by myself, just because it was, obviously not simple, but it wasn't an FYP I was doing myself. It was fine to do it by myself.

8. How did "Working Alone" affect how you felt?
P22: I suppose I probably would have been a little bit less...not anxious...I would have been...yeah, a little bit less anxious if someone else was there working with me.
RESEARCHER: Why would you be less anxious?
P22: Because working with somebody else, it does...they help you and encourage you that you are doing it the right way. I, personally myself, I'm very bad at making decisions, being... this is the right decision to go ahead. I'm such a...all over the place.
RESEARCHER: I know. We'll talk about that in a minute...
P22: That's why I find it a little bit less anxious.

9. Would you have preferred "Working in Pairs"? Why?
P22: Yeah probably, yeah.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You started with The Scarecrow, and you looked at the 1st clue after a few minutes. You did say that you were deeply confused. Then you looked at 2nd clue after 8 minutes in total. You didn't fancy it anymore so you move to The Lamp and

then there was lots of twisting and turning. You were quite comfortable with that. You had the light switched on after 17 minutes in total, less than 6 minutes after you started it. So that was good, because a lot of people never got that far. You had accessed the 1st clue, but that wasn't much use to you because you'd already worked out. Then you open the 2nd clue. Now, that was telling you that the centre rod was so inflexible, but you didn't...you got a bit stuck again. So, then you went on to The Lift after half an hour. You suggested building up from the bottom, which was great because that's "the reframing". The fact that you can't slow the car down or speed the elevator up. You jumped straight to the correct solution. Then 3 ½ minutes later, you realised building from the bottom will cause problems, so you then flipped to what would be the standard solution, really great. Then you extended the arm, and then you extended it with joint pieces that made it a really complex shape, and it got stuck and then you ran out of time. Very frustrating for me...and for you. "She has it!!!"
P22: I just had the piece...I had it horizontally instead of vertically, I was "oh, for God's sake!"
RESEARCHER: Again, we'll be referring to those things later on.

10. How did you feel about dealing with physical puzzles in a learning environment?
P22: I think it's great, learning with your hands and actually doing it, because I'm definitely more...I learn through doing something, rather than just reading it off a PowerPoint.
RESEARCHER: Do you find visualisation difficult?
P22: Sometimes yeah. I definitely prefer [points at puzzles].
RESEARCHER: Yeah, you were...not aggressive, but when you could be, you were definitely fiddling with things a lot. Which was the whole point. Cos if you just stare it, it may as well be a picture.
P22: I'd say I definitely prefer this type of learning rather than just someone telling me about it.

11. How did you feel about your performance with the puzzles?
P22: I was kind of frustrated! Cos, the 1st one [The Scarecrow], I just didn't understand it at all and I didn't get it, and then seeing the solution I was like "oh, I could have got that!" I was happy with the last one [The Lift] because I actually understood it and got some sort of solution that worked. Kind of annoyed about the 1st one, but the other 2....cos I think, with the 1st one, I was...not afraid to start moving it, but because it was the 1st one, I hadn't really gotten into it yet, but by the 2nd one, I was "oh yeah, I can tear these down, I can mess it up" Then, by the 3rd one, I got into it.
RESEARCHER: When you looked at the 1st clue, and it said about Blu-Tack being your friend, you actually picked up some Blu-Tack and were playing with it for the rest of the time.
P22: Yeah I do that.
RESEARCHER: Why?
P22: Especially when I'm sitting at my desk as well, when I'm trying to come up with some ideas, I do fiddle with stuff while I'm thinking in my head. It is something I do.

12. What would you have done differently?
P22: For the 1st one?
RESEARCHER: In general.

P22: I suppose for the 1st one anyway, I should have actually let the car run all the way up to the top, because then I would have seen that the barrels fall down.
RESEARCHER: Yeah, that would have helped.
P22: Yeah I suppose I'm very much in my head, so I would kind of do something and then say "oh that's wrong! I have to do something else" I kind of don't make decisions. I'm "try this first, and see does it work, I suppose"
RESEARCHER: You are very fast with working out at the mechanism for The Lamp, with no clues. You did look up the clues, but it was after you'd worked out what to do. So that was very good. You just had to leap into designing the solution. It seems like you got stuck at, what I would have argued, was the easier part.
P22: Yeah. I don't know what...I think because I didn't...what was it, that the middle one [The Lamp] Was I using the right rod or I didn't pick up...?
RESEARCHER: You took out the rod that was there, and that meant The Lamp turned on. And then...
P22: But the more flexible rod...did I pick up the right one or was it…?
RESEARCHER: No, you didn't know what the clue meant. But it was an odd thing to get stuck on, because working out how The Lamp worked was, I would have thought, harder?
P22: Yeah...maybe I kind of...sometimes I get in my head about stuff like that as well, and I'm "oh no, no, what is this?" I get worried about getting the right thing and then I just kind of everything goes...I can't really think properly, maybe? Probably at that stage, "I'll just move on to the next one" so I say that's what it was.

13. How did the choice element, the ability to direct your learning, affect your thinking?

P22: Having the choice to move on to the next one definitely maybe a little less...serious, if that makes sense? It kind of it made it a little bit more fun, more...I didn't feel pressured yeah I didn't feel pressured that I had to get this one right to move onto the next one, so it was nice just to be able to walk around and do this I suppose.
RESEARCHER repeats question
P22: It did kind of make me a little bit less stressed about the whole thing.
RESEARCHER: Also, you didn't look at any two clues for The Lift, at all.
P22: Yeah.
RESEARCHER: And you were very fast with that.
P22: Did I not look at any clues for the last one? [The Lift]
RESEARCHER: No, not for The Lift. Because you didn't have to.
P22: Yeah, I didn't have to.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P22: Looking at the clues, or having to look at the clues, I felt a little bit defeated. "Oh I can't figure this out, I have to look at it!" But it was also...because it is the learning environment, it is ok just to look at clues sometimes and get a little help. You don't have to do everything by yourself, so was kind of nice to have that option. And then...but the fact that it was an option and I didn't have to use it for the last one kinda made me feel a little bit better that I was actually able to figure it out by myself as well, without having to use the clues.
RESEARCHER: Some people had no emotional engagement with the clues as such, it was just information, and they opened them. If the information's there, I'll use it.

P22: I think the clues do have an emotion. For me it was a little bit of a sense of defeat that you had to look at them and I feel like, I dunno, I feel like most people would feel that way, even if...
RESEARCHER: They have. They felt like it was giving it, but you didn't have to, so you didn't!

15. What was your favourite aspect of learning like this?
P22: It was good that it was fun and interactive, and it was a little bit more than engaging than sitting in a lecture, reading a PowerPoint. You kind of...I think for some people it is better to do it yourself and figure out yourself and you do get a better learning...you come away from it learning more than just from reading words on a screen. For some people anyway...

16. What was your least favourite aspect of learning like this?
P22: Feeling frustrated after the 1st one, not getting it, not being able to understand it or not finding a way. But, the other two made up for it because I did figure out the light switch and I was like ok, I got a little bit of it. And the last one [The Lift] I did figure it out, so I did...maybe having the three of them together, I wasn't fixated just on not getting the 1st one.

17. Did you learn anything useful to you? What?
P22: I suppose I do...if I come in here not knowing...not from a design aspect, maybe if I was a business student or something coming in and learning that you can do things by hand figure things out by doing maybe that way...but I already learnt that way anyway. What else how to use? What are they called?
RESEARCHER: K'Nex
P22: Yeah K'Nex. How to use K'Nex.
RESEARCHER: Get some, build some!

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P22: I don't really know.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P22: Yeah, I think so. After doing it. When you were explaining it earlier as well, today. I didn't really...obviously I understand the concepts, but didn't really realise that's what it was. That there is the difference between reframing and fixation. But at the time, I didn't really understand that's what I was doing, but now looking back, I get it.
RESEARCHER: It wasn't necessary that you understood what the word was, because I've gotten 1st, 2nd, 3rd & 4th Years to do this as well. Some of the 1st Years that did it, it was at the start of term, so that they only had a single term, and most of that was programming and maths, but they still had to solve the puzzle.

20. Do you care?
P22: Yeah! [Indignant tone]
RESEARCHER: Don't hit me,
P22: Yeah it was fun. It was good to do it, and to understand it as well. No, I do.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P22: Yeah I suppose so. There are different solutions and ways to do things, but I kind of have been taught that all the way u. But I am...it was good to do it that way.

C3.23 P23 Transcript

P23: Pair (with P24): iMedia

1. How long have you been studying design?
P23: Well, I had my undergrad…that was 4 years. A year out to work, so that's 5, 6. But, realistically if you take into account studying design, all my life really. I mean, my whole life I've been drawing from a young age. Ever since I started drawing Pokémon when I was a kid. From then on, just continuously. When I got to college then, I did a PLC in Psychology. It's one of the reasons I went for Digital Media [Design] because it had a sociological aspect to it, and seeing how design actually influences people. So a long time.

2. What do you think defines a successful student?
P23: It's hard to define a successful student. I know a lot of people that have done really well in college, come out with a 1:1 but don't use it after because they don't care. So I think someone who cares could be defined as a successful student, because they'll want to do it afterwards. If you're actually interested in what my course was, Digital Media, and you then you qualify and you get a 2:2 or 2:1, but you're really interested and you love what you do, you're going to continue on and do it. So, I think that's what you would consider a successful student.

3. What do you think defines a successful instructor?
P23: To me, a successful instructor is someone who is approachable and can make whatever they're teaching as understandable as possible.

4. Why did you volunteer for this testing with me?
P23: I thought it sounded fun. I thought it was a cool idea to actually try and understand design from a different perspective, looking at it through actually moving things. I thought it was really interesting, and I was talked into it...

5. How do you think the physical nature of the puzzles affected your reasoning?
P23: I would say so, because you're looking at it and you're trying to alter it in a different way than you would from...say if I'm working on a piece of code. Sometimes I'll look at a piece of code and I'll know exactly what's going on, but if you ask me to alter it and change it about, I wouldn't really know what to do. Looking at it...actual pieces, actually being able to move it, it's like being able to move the imagery of what Processing [programming language] might create... be able to move it and see what it does. So I would say...did it affect my reasoning? Yeah, definitely. It probably took me too long for me to be looking around at pieces, because I had to. That's what I was doing a lot, I felt. I was looking at pieces and trying to move them. And I didn't want to break it apart either...cos I'd have to put it back together if I broke it apart. If I got this wrong, I have to go back to it. Also time wasn't issue, so....

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P23: Oh, I cared more!
RESEARCHER: Why?
P23: I suppose it's just you're more in the moment. It's hard to describe. It's almost like when you're watching a movie at home and you can get up and do whatever you want. If you're reading a book, you can just leave it. Compared to when you're in the cinema when you're sat down and staring at this thing, you're more emotionally attached to it. Also time as well helped because I was looking at it thinking "I have to have this done by this time" Sometimes I'll do that when I'm studying, I'll set time for myself. So, yeah, I was definitely more emotionally engaged.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You were working as a pair with Emma. You started with The Lamp, you read the scenario and you began. You removed the centre rod really quickly. After opening clue 1 which was the trigger, you both had a good play with it...while examining the device, so that was interesting. After 10 minutes, Emma suggested...Emma realised the button needed to be released, cos I could she her poking around and that's what she was saying to me. But then, a minute and a half later, at 11:30, Emma, referring to the centre rod that you had broken off said "I wish this would bend" And then she, oddly enough, asked for a pen to draw her solution. Then, you asked for the 2nd clue...which basically said that it had to bend, and then you solved it straight away. So, she was upset that she wasted 8 minutes by not pressing on with what she said. You were a team, so I'm just telling you what happened. Then you solved it. About halfway through your time, you choose The Scarecrow next, you read through it, manipulated the cart by hand, dragging it up and down instead of the slow mechanism. Then you went for the clues. You went for the 2nd first, I'm not sure if she just felt like going for the 2nd one. Then she went for the 1st one. Then you went for the 3rd one, all nice and quick. You put it in motion, but you had no time at all, you get a minute left for The Lift, you didn't even have time to read the scenario, so you didn't look at the clues for The Lift either. The Scarecrow one worked, so you get 2 done. That was good. You manipulated The Lamp structure for about 5 minutes before removing any pieces, lots of picking it up and twisting and turning it around, and the...that makes sense because of what you said, you were thinking "if I remove anything, I'll have to put back" OK, that's just a quick review as a reminder. Though as it turns out, most of the students had no problem remembering what they did. So, we'll go through the relevant bits at the moment but...

7. How did "Working in Pairs" affect your thinking?
P23: I enjoy working in teams as it is. I kinda wish, going back on it that I listened to what Emma said.
RESEARCHER; Well she wished she'd listened to what she said as well.
P23: I kind of felt we were trying to work on it...it was probably a bit more difficult, I suppose, for something like this because you only had 1 piece to look at, and both of us for example...I don't know what Emma was feeling, maybe she wanted to move it while I had it in my hands or something. That might have been an issue, I'm only thinking about it now. But I usually enjoy working in pairs. And I think if I wasn't, if I was just me there, I don't know if I would have solved it as quick either. I'm pretty confident

that I wouldn’t, cos another thing is that...I wouldn't have forced myself to go for a clue. I know that.
RESEARCHER: A source of shame I think you said. Yeah.
P23: It’s just...did I actually say that?
RESEARCHER: You did, yeah “they feel like a source of shame”
P23: Yeah. So I definitely felt I wouldn’t have got the...maybe ⅔. I don’t think so.

8. How did “Working in Pairs” affect how you felt?
P23: Not really. I don’t know if it affected me. I think I’d be more...I get more into it if it’s a pair, because it’s just this group mentality. It’s like when you're working in design, you're always in a group, for example, a workshop for example, I feel like I get a lot more done then, because you're bouncing ideas off each other continuously. And again, I don't think that...maybe I wouldn’t have been...as emotionally attached if it wasn’t for being with somebody here.

9. Would you have preferred Working Alone? Why?
P23: No. No I don't think so.

9a. Were you comfortable with voicing your opinion?
P23: Yes. I would say so. With Emma yes...but it depends.
RESEARCHER: If I’d paired you randomly with someone you didn’t know?
P23: If it was random, I don’t think so. I feel like, if you put someone in there that I didn't know, and had a strong voice, who was “we’re doing this, we’re doing that!” then you just followed, like a sheep.

10. How did you feel about dealing with physical puzzles in a learning environment?
P23: I think it's a really cool idea.
RESEARCHER: Why?
P23: Like I said, it's the emotional aspect of it. You just get more attached to it. There’s times...I don't know how many hours I've spent in lectures and just falling asleep and not paying attention, even in Labs. And you’re just copying and pasting stuff sometimes. This just makes a massive difference because you actually have to do something. And you can see your results immediately as well.
RESEARCHER: That's true yeah. You can see whether it’s done or not.
P23: Seeing that...when we pushed down on The Lamp, and the light came on, “this is amazing!”
RESEARCHER: Nobel Prize for you!

11. How did you feel about your performance with the puzzles?
P23: Good, but...like I was happy to get the 2 of them. The 2nd one I wish that we got quicker because I feel like I knew what to do.
RESEARCHER: Those 8 minutes...let's go with 9 minutes that were wasted...that's a mean way of putting it but...yes, that would have been comfortably enough time to do The Lift.
P23: It's also not being able to get to The Lift is frustrating.
RESEARCHER: Yeah.
P23: Very frustrating.

12. What would you have done differently?
P23: I would have jumped for the...I don't think I understood being able to use all the objects. I remember when we were using Blu Tack to hold up the barrels, I feel like if I knew...if I've understood that more, I would have used it immediately, or a lot quicker...and I probably would have found it out a lot quicker as well. Also the cards [clues], I probably should have jumped for them a lot quicker. I know Emma definitely asked one or two times.
RESEARCHER: She wanted the clues more than you did. But, it was your choice. Some would prefer to fail gloriously, a stubbornness...with some people, it was like Christmas morning, after 5 minutes every clue was out. Everyone's different.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P23: It's just going back wanting to...when you choose something like that, when I chose The Lamp, you're kinda stuck on it and you want to complete it before jumping onto the next one, and also having the option of jumping on, I feel like there was...jumping away from it. I feel like was there was the aspect of failure there as well. You're not saying "you have to move on to next one" that would have hurt! But me leaving it there would be worse, because it's my decision and I would have felt awful about it.

14. How did the choice element, the ability to direct your learning, affect how you felt?
P23: I liked it, yeah. I really did.
RESEARCHER: It is true that...I would say there is in order that if you do them in, it's easier. And I didn't give anyone that help.
P23: Is just through timing?
RESEARCHER: I'd say if you did The Lift first, you'd have it done quickly, and then The Scarecrow...The Lamp, once you work out it's the middle bar, it's easy. But until you do, it's very hard. So maybe depending on the way your mind works, if you're very machine-like in your thinking, The Lamp second, and then The Scarecrow. But if you're a bit more off-the-wall, I'd go with The Scarecrow in the middle, and see what happens with The Lamp. But I didn't give that guidance.
P23: But I like the idea of...I didn't know any of the...what they were going to do, or know what the answers...I obviously didn't know what the answer was going to be. I liked the idea of not knowing and just jumping in.
RESEARCHER: You definitely wanted to do them without the clues?
P23: Yeah!
RESEARCHER: Definitely.

15. What was your favourite aspect of learning like this?
P23: Being able to play with puzzles, I felt like a child doing it. And actually learning and again, having an end product makes all the difference. Seeing what you've done makes a massive difference. It's not like when you're handing up an assignment, you've to wait two or three months before you get an answer from it.

16. What was your least favourite aspect of learning like this?
P23: The best bits of the whole thing? I don't know. I suppose maybe just being stressed about not being able to do certain parts of it...or the timing maybe? The restraint was

there so that was always on my mind throughout the whole thing. But it also can be seen as a positive because it made it way more exciting and the time flew by.
RESEARCHER: 2 people out of 31 solved all 3. But was another 10 that were hot-on-the-heels...another 5 or 10 minutes and they would have done all 3. That appears to have worked out well enough, from my point of view anyway.

17. Did you learn anything useful to you? What?
P23: The Scarecrow in particular, the context around it in terms of design was really interesting. Actually be able to see the Batman and the Scarecrow, and you actually have something there to work with. Whereas if you just said "move this barrel up and hide it from whoever" maybe I wouldn't have been as...excited by it, or interested in it. But the fact that you had an actual context, an idea there, I was thinking about it while I was doing it.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P23: The whole thing was interesting. I think the idea being able to move parts and just to answer a question that you don't know what the question is, is really interesting.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P23: Understanding it? I'm not sure if it's really made that much of a difference. I think if you did put the same ideas in front of me on a piece of paper and asked me to solve it, I wouldn't have been as interested in it. I wouldn't have wanted to do it. But actually understanding the context, maybe if I drew it out, I would get it after a while. But I think a combination of both will be really interesting, actually being able to...it's just that...we didn't really have...we were allowed to use paper and draw stuff out, but I think after a while...I remember when we were using the barrels, trying to find ways about it. I was able to test it a lot quicker than me just thinking about it and writing it down. So that's really good!

20. Do you care?
P23: No I do. 100%. I know a lot of people that have been in college and don't really care too much. They could have done quite well, don't really care. But my whole family...I would have always...I went to college because my older brother went to college. That forced me to do it. Then I look at my younger brother, and he doesn't care about that side of things and I can't really see how he doesn't want to do that. Whereas I'm...I was off last year when I finished my course, I still signed up for all these lynda.com courses...just to learn, because it's something to do, and it's not playing games, I suppose.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P23: Yeah. I think so. In terms of being able to come up with a solution based on users. "Users" is the most common word in our course. It's just...crazy...when you look at...when I was looking at this, I was thinking about everything in terms of the stakeholders and what's exactly been affected, so I think that definitely helps. And I think if you put it into more...if you were able to look at more design ideas and solutions, you could come up with things just like this, and implement it in different ways, which I imagine is what you are looking into anyway. Yeah, it was definitely helpful, the idea

of you being able to come up with an answer within a certain time frame is also helpful and is way more emotionally engaging.
RESEARCHER: Well, you did manage to replicate great engineers' work...
P23: Yeah, exactly!
RESEARCHER: ...in 45 minutes!

C3.24 P24 Transcript

P24: Pair (with P23): iMedia

1. How long have you been studying design?
P24: I don't know...because I went to Art College and did Fine Arts. I don't really think that counts as design. So, maybe just this year.
RESEARCHER: Ok, I was going to ask you what you did.
P24: So I did Fine Art, it wasn't exactly design really, so I would say this year.

2. What do you think defines a successful student?
P24: In general, or a Design Student?
RESEARCHER: Your opinion.
P24: Someone who works hard, manages their time well, that's very important I think, that's probably number one. Yeah, time management deadlines, setting your own deadlines. That's what I do. I set them before they're due and then I manage my time up until then, so that I still have time to fix things if they're ruined, so that's using myself as an example of a successful student...

3. What do you think defines a successful instructor?
P24: Like a tutor, or a lecturer?
RESEARCHER: A person teaching you.
P24: Someone who is really engaging, and engaged with the class and the students, not just standing there and reading off the board. Like you were saying earlier, using examples and contextualising them into something that students would understand, and then reframing things if people don't get something, instead of being "this is the way it is!" you know? Something that engages everybody, not just a one-sided conversation. It's a two-sided conversation.

4. Why did you volunteer for this testing with me?
P24: I wanted to help you! And I thought it sounds really interesting, and I like Lego, and I'm interested in design, so...and anything involving in that and seeing what other people are doing in the industry is always interesting.

5. How do you think the physical nature of the puzzles affected your reasoning?
P24: I think I'm a better thinker when I'm touching stuff.
RESEARCHER: Why?
P24: I went to Art College, so it was much more physical nature in everything that we did anyway. Learning by doing, I suppose, instead of just thinking. Even if I'm thinking about something, I'd have to write it down.
RESEARCHER: You were the only person to request a pen and paper. Why was that?

P24: Why was that? I can think better when I can visualise something in the way I see it, if that makes sense?
RESEARCHER: Yeah, just asking why. OK...as opposed to if I drew something on a board and said this...figure this out. You still like drawing.
P24: Yeah, and being able to re-work something, I feel that there's something static about drawing and it's hard to re-figure in a way that...like you know sometimes you turn something upside down and you're "oh, I get it now!" Like that.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P24: I was much more determined, I would say. To actually get it, to solve it. Like I feel like if I was sitting down... figure it out. Because it's there in front of me and I'm "I need to get this done!" and being able to play with it and re-work it.

7. How did "Working in Pairs" affect your thinking?
P24: I actually did think a good bit about this one. It's a good question. I think it was a lot better to work in pairs, cos you guys weren't really allowed say anything to us, whereas me and Sean could bounce things off each other. Or he could say something that would spark something and I'd be like "oh crap!" and it would lead onto something else.
RESEARCHER: You liked that?
P24: Yeah.

8. How did "Working in Pairs" affect how you felt?
P24: I did feel a bit competitive...
RESEARCHER: Even though you're supposed to be in a team.
P24: Yeah, a little bit. I felt like I didn't want to be left behind or I didn't want to be not contributing as much as my partner.

9. Would you have preferred Working Alone? Why?
P24: Depends on the project. With this, no. I think it was fun to do it with something else. Especially when you're figuring something out. In general, I prefer to work alone.

9a. Were you comfortable with voicing your opinion?
P24: Yeah.
RESEARCHER: Why?
P24: Because you told us there are no wrong answers, and it felt like a "safe space" to speak about my opinion, whether it be wrong or right or wrong, it didn't matter.
RESEARCHER: One of the instructions that you were giving it as a pair is that you have to work on a puzzle at the same time. What you comfortable with that negotiation?
P24: Yeah, yeah. I was just like "come on, move on!" and then he was "no!" and then I was "COME ON!" and then we did, so…

[REFERRING TO VIDEO NOTES]
RESEARCHER: You read through The Lamp scenario and you began. At 7 minutes, you had the 1st clue, which was the switch, so it was in your hand, so I was describing how it works. After 10 minutes, you realised...how the button needed to be released, and then a minute later you said out loud, cos I checked the tape, "I wish this would bend!"

P24: I know!
RESEARCHER: Then you asked for a pen and paper...it was another 7 minutes after the pen and paper and 8 minutes after you saying that, that you opened the 2nd clue, and then it was telling you that the centre rod is inflexible. So, a minute later, 2 minutes later, sorry...it took you a minute and a half after seeing the 2nd clue to completely solve it. As opposed to solving it when you said it. So you solved it at 21 minutes. If you had acted on you saying "I wish this would bend", you would have solved it 14 minutes...sorry 13 minutes.
P24: I know. Would have been really impressive?
RESEARCHER: Very, yes. It was just very frustrating that you said "I wish this could bend!
P24: I know and I knew the one bended as well!
RESEARCHER: You'd had a tutorial before.
P24: Yeah, I was like "it bends!" I completely second-guess myself, I don't know why.
RESEARCHER: You don't know why?
P24: No.
RESEARCHER: Because you did! You second-guessed yourself! You said something out loud that you knew how to do, and you just didn't do it.
P24: I think I just assumed I was wrong before I even tested it.
RESEARCHER: Aww!
P24: I know.
RESEARCHER: You went to The Scarecrow, you manipulated the cart by hand, so why did you do that? As in, you were dragging it up and down with the string.
P24: It was so slow...the motor!
RESEARCHER: Why did you do it at all?
P24: Just to test it.
RESEARCHER: What do you mean "test it"?
P24: To test every time, instead of running the motor to see if it would go up and then if it would be hidden, you could just run it up really quickly, test it, see if we could see it. If we could see it, drop it down and try it again.
RESEARCHER: You solved that one, and then you moved to The Lift, but you had no time at all. You had about a minute from start to finish, so that wasn't really an attempt.

10. How did you feel about dealing with physical puzzles in a learning environment?
P24: I think it works better.
RESEARCHER: For you?
P24: Yeah. I definitely think so.
RESEARCHER: Why?
P24: Just the physical aspect of being able to think it through. I said about testing the car, instead of having to visualise it, which can be difficult with things like that…"there's trains and a track!" and it's like a maths question, and I was getting lost in them, and can't think any further past! But I did find...I felt there was very specific ways of thinking behind each of them, and I found that the train/car one [The Scarecrow] much harder than the...the light one [Dalen Lamp], whereas Sean found that one [The Scarecrow] really easy and he couldn't get the light one.
RESEARCHER: Most people found The Lamp hard.
P24: And then I feel like this one has a completely different way of thinking around it as well. So I feel like it taught me that whatever that lamp thing is, that somehow relates

to the way that I think about things...because I really couldn't get my head around this one!
RESEARCHER: The Scarecrow?
P24: [nods in confirmation] But Sean did, yeah.
RESEARCHER: Well people are different, and they bring different skills and knowledge to it. I did...you were replicating the life's work of people in 15 minutes, so there is enough clues to force you down a particular way of thinking.
P24: Yeah!
RESEARCHER: Because the solution exists in my head but not in yours, so as a learning experience it is coherent, but yes, I do have a lot of subtle things to help you to funnel your thinking slightly because otherwise I'm asking you to replicate, say for example, a Nobel Prize winning stroke of insight in 15 minutes, which is putting a lot of pressure on you. You still did it; you did the same thing that that person did. That was very impressive so...well done!

11. How did you feel about your performance with the puzzles?
P24: I am disappointed in myself that I didn't just try that stupid bendy stick in there when I said it, and then I feel like we would have had more time to get all of them done.
RESEARCHER: If things had continued on as they were, you would have had 9 minutes to do the elevator.
P24: And you said that the easiest one.
RESEARCHER: A lot of people did it in under 9, so yeah.
P24: We would have got them all.
RESEARCHER: Bitter...
P24: Disappointed!

12. What would you have done differently?
P24: Not second guessed myself.
RESEARCHER: Yeah.
P24: Trust my instincts.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P24: Be able to choose?
RESEARCHER: As opposed to how you felt about it. The fact that you knew you could go from one to the other without finishing one, that you could access clues that I told you were helpful, or not access them.
P24: I feel like when you're doing it, it makes more sense to do one and finish it and move on, instead of moving between.
RESEARCHER: I didn't tell you which one to start with, though. Was that a good or bad thing?
P24: No, I thought that was a good thing. I guess it shows you what people are more drawn to. I dunno...I guess it's a bit weird that we went for the small one, but everyone probably went for the big ones.
RESEARCHER: No. A lot of people start with The Lamp, even though I would class that...statistically, it's by far the hardest.
P24: Yeah, I dunno why. Maybe because it's smaller, it seems like it would be easier to solve.
RESEARCHER: Cos you had no issue picking it up. You were quite manipulative with it and fiddling about with it. The others don't really allow you to pick them up at least.

P24: Yeah, exactly. And it’s a lamp and I suppose that's a word that everyone knows.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P24: Flustered!
RESEARCHER: Why?
P24: Because I was “oh no, which one will I pick?” I guess you’re like “ok, I should pick the one that’s easiest to start off with, go from easy to hard, get them out of the way!”
RESEARCHER: So if I’d listed them...I would have listed them “the Lift 1st, then Scarecrow, then The Lamp”
P24: As?
RESEARCHER: Easy to hard. So you started on what turns out to be the hardest one.
P24: Yeah. I didn't know that, though.
RESEARCHER: Well, I didn't either! I knew The Lift was the easiest, but I thought The Lamp would be moderate and The Scarecrow would be hardest, but that was me guessing. It turned the other way around.
P24: That's the thing though! You don't know what could be relative to each person. I still can't really get my head around that one [The Scarecrow] and I didn't get a chance to try the elevator one, but I just found The Lamp one...I found that one OK.
RESEARCHER: I am only guessing; I think I would have solved The Lamp quicker than the other two because that's the way my mind works. There's something holding the switch in place. There it is. I’d better do something so that doesn't move out of place. Done. It’s just the way my head is. So, how did the choice element affect how you felt, I was thinking of? You were a bit stressed over too much choice?
P24: Yeah. I suppose yeah. Like a kid in a candy shop, not sure where to go first. And then the time was running and you getting stressed out, you’re “I have to pick one now!” Then because you're in a team, I'm think Sean and me were “right, just get this done!”
RESEARCHER: Well, you had no problem accessing the clues. I've “none” down for The Lift, because you had no time. So, with The Lamp, you spent a bit of time, then access a clue, spent a bit more time, access another clue, then you solved it. So the fact that you didn’t access the 2nd clue is irrelevant. Then you move to The Scarecrow, and you were clearly struggling, so you accessed the 3 clues within 6 minutes and then solved it. You knew you were running out of time though?
P24: Yeah.
RESEARCHER: So how did you feel about the clues? For example, you don't appear to have any issue using them. Were you fine with using them or did you feel anything negative about it?
P24: No. I can see how other people would feel guilty about using the clues, but...
RESEARCHER: “The clues feel like a source of shame”, it was the exact expression.
P24: From other people?
RESEARCHER: From you.
P24: They do, I can totally see.
RESEARCHER: You said it.
P24: Did I? Are you quoting me to me?
RESEARCHER: I am, yeah.
P24: I can see how other people, because I can tell...I know Sean very well, I could tell he didn't want to use any of the clues at all, because it seems like...like you’re admitting that you need help. But...
RESEARCHER: You were fine with that?

P24: No, yeah...I don't think there's anything wrong with...everything is for...it's like in any learning environment, everything is there for you to get to the end point and however you do that, no one's going to be like "someone helped you?"
RESEARCHER: Fine so, just checking.

15. What was your favourite aspect of learning like this?
P24: The play element to it. I thought that was fun. It was also very engaging...than a lecture form...of this nature.

16. What was your least favourite aspect of learning like this?
P24: The time pressure!
RESEARCHER: You said that out loud.
P24: What did I say?
RESEARCHER: You were very...I clearly hadn't made it clear enough that you had 45 minutes, and you went "WHAT!" and you snapped a little bit at me because...The Lamp took up half your time, and...
P24: Yeah.
RESEARCHER: I'm not too sure how knowing it was exactly 45 would have affected the pacing but you were annoyed knowing that there was less time than you were hoping was left...the time pressure. Why did you not like that? Was it pressurized while you're doing it or just that you were running out of it?
P24: Both. If there was no time limit on it, I feel like...that was a constraint, I suppose on it. If it wasn't there, you could take your time and go through all of them and I probably would have been "oh yeah" and maybe if that pressure wasn't there, I would have...solved them quicker.
RESEARCHER: Do you think you would have done it quicker without the additional pressure?
P24: Maybe, but I don't know. I can't really tell.
RESEARCHER: Would that not have taken away from the game, or challenge part?
P24: It would have definitely taken with the game aspect of it. And also, when there's no time limit, I feel like maybe...you would relax a bit or you would be "I don't even care anymore". Cos there's no end goal, just be like "whatever!"

17. Did you learn anything useful to you? What?
P24: Yeah. I definitely learned...cos we were literally reframing The Lamp, to try and make it work again. So solving the problem by quite literally changing it so that we could make sense of it, and also I learned that I clearly second-guess myself quite a lot. Or I don't. I'm still annoyed. I'm actually still annoyed about it that I didn't...
RESEARCHER: I was annoyed on your behalf.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P24: Yeah. Like I said to you earlier, I thought it was interesting...like I said, I feel like you can tell what kind of person people are by what they're drawn to, like the way that they think. Like I said Sean was really drawn to this one.
RESEARCHER: The Scarecrow one.
P24: Yeah, and he could figure that out and it's like he knew where it was going, whereas I was like "I've no idea where this is going" I was just trying to solve it as we went along. And with The Lamp one, I kind of had more of an idea of where that was

going. It was more like a problem, I don't know...I guess they're all different types of problems, and I guess I feel like it tells a lot about the person which one they drawn to.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P24: Yeah, I think so.

20. Do you care?
P24: Yes.
RESEARCHER: I know that seems like an odd question. Why?
P24: Because...for learning in general I think it's important to be able to reframe things and contextualize them in your own way so you understand them. It's all well and good to know one example of something, but it's not exactly understanding or learning, it's just an example.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P24: Yeah I think so. And especially what I said about the elements of play, and you're talking about reframing ideas. It reminds me of iterating. When you're doing a design and you have to make iterations on it because it's not working. It's kind of like that.

C3.25 P25 Transcript

P25: Single: DMD 4th Year

1. How long have you been studying design?
P25: I've been studying it for 3 years, 1st year, 2nd Year, this is half of 3rd year...so 2 ½ years really, just the first 3 months of this year so far. That's about as long as I've been doing it.

2. What do you think defines a successful student?
P25: Someone who...I wouldn't say it's to do a career or grades. It's more to do with the individual and what they feel they got out of it. I think it's a lot to do with the person being able to use that they learn in day-to-day life or in their career...and not necessarily to do with being CEO of a multimillion-dollar company because they did so well. I don't think it's necessarily success in career terms...more so how you feel about it and how you use the things you learnt and how you value...how you would...what's the word? Well, how you value it rather than...how does student values it rather than...what we would...the average person would value in a way...like career and grades, if you get me?

3. What do you think defines a successful instructor?
P25: Someone who's clear and at least willing to elaborate whenever student asks a question. I think someone who is just approachable...yeah just mainly approachable and willing to put it in simpler terms and help. I think that's what I would define as a successful instructor anyway.

4. Why did you volunteer for this testing with me?
P25: It just seems like an interesting subject. You said yourself so it's something that hasn't really been tested, so I thought that was interesting to be part of that, but also because it seems like...because I don't think...I just think looking into how people learn and what ways to teach them, it's just a really interesting thing and something that's really important as well, very valuable to society in general. So that's why I volunteered.

5. How do you think the physical nature of the puzzles affected your reasoning?
P25: I think it definitely helped a lot more. It affected me because I felt like I could try stuff out that wouldn't work, and I could go back on it. I wasn't necessarily stuck, cos I always...it's not like a maths question, you know? When you have a maths question, you have your one method, you go through it on paper and then you spent 20 minutes and that turns out it's the wrong method, you gotta go right back to the start. Whereas with this, I could go come up with a halfway thing, and then diverge in different directions, and then I could easily to go back to my last reasoning. So, I think it definitely made me a little bit more adventurous with it, cos I'm not normally adventurous at all when it comes to puzzles or anything like that. I just kinda stick to my one idea. I did do that a little bit too, but I think it was...I think I kinda...was a bit more lackadaisical with it, sometimes, so yeah.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P25: I think I was a lot more happy to do it. I think it was just like...again...if it was just like...on a piece of paper, just a logic puzzle, like a riddle or something...they did come with a little prompt, this is how it's meant to go. So yeah, I think it's definitely peaked my interest a lot more. I felt a lot more excited to do it, a lot happier with it, and I didn't feel as frustrated because when I get a riddle, I'm always stuck on it for ages but with that...I was fine even if I did get stuck, I was still...there's still plenty of things I can try. I never felt too frustrated with it.

7. How did "Working Alone" affect your thinking?
P25: I think I would rely a lot more on the other person, sometimes. I think I relax a lot more when I'm working in a pair. Which is always something I'm concerned about. I felt like I had to come up with my own ideas. I had to come up with my own reasoning and putting stuff together, but I definitely think I would have taken a backseat if I've been working with someone.

8. How did "Working Alone" affect how you felt?
P25: I was a little bit intimidated, because again because I don't have something to fall back on. You don't have another person there also struggling, so you don't feel as bad about it. Or figuring most of it out on your behalf because they're smarter or better at the puzzles. So, I felt a lot more intimidated, but I also felt a lot more free because I also didn't have another person doing the puzzles with me and judging me and my suggestions so I kind of felt free to do whatever I wanted.

9. Would you have preferred "Working in Pairs"? Why?
P25: No, I liked it by myself.
RESEARCHER: Why is that?

P25: I guess...the reasons I stated but sometimes working in pairs you can frustrate each other a little bit. So, if it's only two people, it's hard to pick a leader out of that. If one person comes up with a theory, and then the other person also has a theory, you have to battle them out; you can't test both of them the same time. So you've gotta always do one first, so that would take away more time as well. So I think working alone is a lot more efficient, in a way.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You read through all three scenarios and examined all three parcels before you picked one. Why did you do it that way?
P25: I suppose it's kind of me playing the PlayStation all the time, you start with the easiest part and then you work your way up. I guess I just thought "Which is the one I think I can solve the quickest, and which is the one that I can solve the longest?", but then I went back on that later on when I did the 1st one [The Slow Elevator], I was "I think they're all going to be equally hard", so I went for the light puzzle [The Dalén Lamp], which I thought initially would be the hardest because it seems the most out of my realm of thinking, but the more I looked at it, the more I was getting from it. So I kind of felt they were all on an equal footing in terms of difficulty after the 1st one, in a way. So I went back on it then.
RESEARCHER: After you read through all three, you started with The Lift. You looked at the 1st clue quite quickly, mulled it over a bit more, then the 2nd clue, then you solved it...you solved it quite quickly in your head because you said what the solution was, it just took a while to build it...
P25: Yeah it was just putting it together.
RESEARCHER: But then you moved onto...The Lamp. You took the back off The Lamp, and the light came on. So you had a full understanding of the mechanism a few minutes after you started.
P25: Yeah.
RESEARCHER: But then you got stuck and you went on to The Scarecrow. Then you had a look at a couple of clues as you were running out of time.
P25: Couldn't help myself!
RESEARCHER: That's interesting. How did you feel about the clues?
P25: I thought the clothes were kind of interesting. They were never really...well, except for the 3rd one on The Scarecrow. When you showed it to me at the end afterwards...they don't directly give you the answer. They give you like...
RESEARCHER: They're not a clue anymore then!
P25: Yeah exactly yeah. They were vague approximations as to what you're meant to do. I remember I read, I think it was one of the ones for The Lamp. I was very confused by it.
RESEARCHER: The Lamp, what you did was you looked at the 1st clue that was the switch. So you had it out in your hand.
P25: There was one of them I remember. I had to think about it for a second and putting it together. I like how vague they were. They were definitely...I felt kinda guilty but I was also like "I'm gonna frustrate myself!"
RESEARCHER: Why do you feel guilty?
P25: Because...it's just like you feel like you should do it yourself, the whole puzzle without the clues, just keep going until you have it. But I was also aware of the time limit, so I was thinking "the clues will make me go quicker" so that was my reasoning. But it did feel a little like "I shouldn't do this but I will" I think it's just like...I wouldn't

say human nature, I suppose...just my nature. I feel like I should do it by myself, but also it's there.
RESEARCHER: It's a common enough reaction. People treating them like lives in a game, and using 1 up.

10. How did you feel about dealing with physical puzzles in a learning environment?
P25: I actually really liked it. I thought it was a really good idea, because I feel a lot of time...I guess it's just...a physical presence of something is far more powerful to me then something on a lecture slide. I found that when I was doing the Leaving Cert for Geography, you'd see all these rock formations in different pictures in your books and stuff. We got do a trip to a beach once, and they were demonstrating actual...the waves crashing on the beach and coastal drift and stuff like that...I think that's what it's called. It made a lot more sense in my head even that they weren't difficult concepts, but I was seeing it physically happen and actively participating in it. So, we were actually doing exercises...we were throwing an orange in the water and then using a metre stick on the shore to track it down to see how far it would travel over the course of a few minutes. I always felt that was...that was more invested in that little simple thing that anyone could do then I was in a lot of the long notes I was taking. So I thought actually getting to approach problems and trying to solve them yourself in little physical things, cos I always thought it was difficult for Engineering students, cos obviously they can't...you're teaching them to build a bridge or something like that but you obviously can't let them build an actual bridge until they're qualified and everything like that, so it's all just on paper.
RESEARCHER: Actually, they make...have you ever seen them down near the Schumann Building? They make them...
P25: Oh, they make physical little…?
RESEARCHER: They make a bridge that's pretty much Action Man scale. Their Instructors are in wellys and fishing gear and they...they build it across the span of the thing. But, as you said, it does make it easier, that even though the Maths that they do help them with making calculations, but they do actually have a go at building a baby version of it. So, at least that's some help to them.

11. How did you feel about your performance with the puzzles?
P25: I thought it was ok. I mean...I remember you said on the last one [The Scarecrow], I was very close to figuring it out, but I was just short. I think it was because I lock myself into the 1st thing I think of sometimes, until it absolutely does not work, and then I'll go back on it. Because I felt with the elevator sometimes, I was too far in to on my answer and I wasn't sure if this is working, I'm not sure, and then eventually it worked so that was fine. The Lamp, I just couldn't really...there was nothing coming to me, so I was...I'll go back to it, and with The Scarecrow one, I was half and half on it. I feel like I can do this, but I also feel that it's gonna...I'm going to have a sudden realisation of "I can't believe I didn't think of that earlier!" As you pointed out a couple of times that I can use the Post-it notes [coloured card] and the Blu-Tack throughout. Because I didn't use them for the other two, so I assumed that are just there if I want to leave a note on something.
RESEARCHER: There was some things that you didn't need it I couldn't just put the pieces you'd need...

P25: Just that would make it too obvious. It was very...the way I think; I'm trying to brute force my way. I don't even consider putting a bit of card there. I considered using Blu-Tack at one point, but that was as close as I got. I think it was...
RESEARCHER: That's called Fixation, when designers get stuck and...it's the opposite of Reframing in this case. They pick a thing and everything to do is based on that being a fact. It's just the way it is. Whereas the Reframing is letting go of those...making it easier for yourself. You learned about Fixation so, by accident!

12. What would you have done differently?
P25: I definitely would have been a bit more adventurous, I think, looking back on it. Well, I was definitely a bit more "I can do whatever, I can remove pieces" I remember with The Lamp, I wouldn't have considered taking the whole back of it off until I asked and you said "Yeah, take it apart. I'll put it back together if it's broken" I didn't do that much for the 1st one until a bit in. I was even a bit cautious about it. I think I would have been a bit more adventurous like that, taking them apart and be willing to try something out that in your head, it seems like a stupid idea but it just might work. Maybe in some cases, that's where your best ideas come from? I definitely would have been more "jumping in head first".
13. How did the choice element, the ability to direct your learning, affect your thinking?
P25: Kind of...I don't really know. I felt a bit different about each one, like The Scarecrow one seemed the way I was looking at it. This is going to have a kind-of simple answer, but it's going to take me ages to get it, something that clicks. Whereas the elevator one seems like something I could solve relatively easy, just making the elevator faster, but then when you try and go and do it...
RESEARCHER: Repeats question.
P25: That I could choose whichever way I wanted to approach? Yeah, definitely. Because...when you're given choices, I think you definitely do that thing where you fixate on a couple of them, like suggestions from people. I noticed that would people suggest something to me, I got that stuck in my head and I just base everything of the suggestions sometimes. So it definitely makes it harder to branch out a bit. But, I think the choice made me feel a bit more nervous but also...willing to try it, in a way. Because, if I...if you were given choices on how to fix this, "try these four different methods, choose one of these four methods", or something like that, I don't think I would've...enjoyed it as much or learned as much, because I feel like that would be giving you the answer straight away, whereas the fact that I was free to figure it out myself was a lot more beneficial, to me at least.

14. How did the choice element, the ability to direct your learning, affect how you felt?
RESEARCHER: You would have preferred the way it was? Would you have preferred more guidance, in the sense of me telling you, giving you less options?
P25: I don't know, because I feel like the clues did help a little bit but...no, I think it was perfect the way it was, in a way. I just wish I almost...I wish I kinda...suppose knew or prepared myself a bit more coming in, because when...I just heard it was puzzles and I hadn't really asked anyone what it was. So I just assumed it was going to be a little Rubik's Cube vague thing. I never would have imagined those [points at puzzles] but I do like that as it is. Yeah.

15. What was your favourite aspect of learning like this?

P25: I guess it was being able to physically being able to have it there. I always have problems visualising things, in a way. I visualise something, and the actual thing doesn't come out the way I visualised it exactly. That throws me off a lot. I think having it actually there in front of you in a physical interactive way, I think that really...I really enjoyed that anyway. It felt better then...trying to figure out a problem with just a pen and paper. Obviously I don't know how feasible it would be to actually do a physical life size one, or something that actively works. Like that elevator problem is difficult to create in an actual building.
RESEARCHER: Yes, it would. I had to go for scale! And considering The Scarecrow is a representation of the Formula 1 problem, I couldn't have something going at 200 miles an hour!
P25: Yeah, you couldn't put a Formula 1 car in here! I get that!
RESEARCHER: Yeah, awkward.
P25: But, I think definitely making smaller scale versions with Lego or K'Nex is a really interesting way of doing it. I thought that was really cool.

16. What was your least favourite aspect of learning like this?
P25: Them being puzzles, in a way! Cos, I'm always really bad at puzzles. But also...I didn't hate it, if you get me? It was just more...I always this problem with puzzles of just never getting to the end. I can get to a certain point and I get stuck and I can't get anywhere.
RESEARCHER: During the video, there was lots of laughing, like nervous laughing, and I thought "he's either really enjoyed this or that's how he expresses his nervousness"
P25: I was enjoying it! I did enjoy it more than I've enjoyed most puzzles. It felt more like a puzzle in a game, where it's sort of interactive and physical than it does a real-life puzzle, like a jigsaw puzzle or Rubik's Cube. Well I definitely don't always like puzzles, but this actually made me like them! But I would still say the actual tackling them like that, I guess it's that you feel silly when you don't figure it out, and you have to be told the answer. But I don't think there's a way to alleviate that.
RESEARCHER: There were timed specifically to make it, not impossible, but pushing it to finish. As it was only 2 people out of 30 finished all 3. I say if I'd made it an hour long, there was a lot of 7 or 8 who had done 2 and were minutes away...I'd say if it been an hour, I could have had 10 people solving all 3. It was timed to force you to choose to do things so not solving all 3 is perfectly normal.
P25: That's kind of the baseline.
RESEARCHER: That what I was trying for. I was trying to work on them so it would time out like that.

17. Did you learn anything useful to you? What?
P25: I learnt a bit about myself, in a way. That I'm not completely silly when it comes to those things, the actual physical puzzles. I learned...I also learned about the examples you gave, actually interesting. The Formula 1 thing was really interesting to me. I'd never heard of that before. I thought that was...very interesting.
RESEARCHER: It was from long ago, but...it's often given as an example to Engineers, this is creative thinking.
P25: I also learned...just that reframing thing in general was really valuable. I caught myself using it to a certain degree, just reframing problems that I have in a simpler

sense. Like I'll wake up one morning and “I’ve got 20 things to do today!” I’ll just take a step back and look at them...these 5 separate things, I’m saying to myself, are all the one thing that I can sort in one move with just talking to these certain people. I did feel that the whole idea works practically in life, and in design. I felt like that was really valuable.

18. Did you learn anything that was interesting to you, and not just useful to know? What?

P25: Also the 3 examples you gave, the Formula 1 car, the elevator, just keep the people occupied rather than making it go faster, and the light you gave, that won the Nobel Prize, yeah?

RESEARCHER: I didn't. I'm not that old!

P25: Yeah, not this K’Nex model!

RESEARCHER: The same reasoning.

P25: Yeah. I just like researching stuff like that by myself on my computer when I’m bored. I just always found that really interesting. I guess it’s kinda useful, yeah, it was just really interesting!

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?

P25: Yeah, I definitely figured out a lot more about like...because obviously what you said about me getting stuck into one thing, Fixation.

RESEARCHER: You knew about that before you came in here.

P25: Yeah, I knew about that. I just didn't know what it was called, or how to change it. I guess this “looking at things in a much simpler way” rather than sticking to the 1st idea that comes into your head, which I always find myself doing anyway.

RESEARCHER: The fixation happens to people more experienced than you, because partially they now have more confidence and knowledge. They tend to be more sure of their opinions so they end up getting fixated when they’re learning, not so much when they’re getting a bit advanced, and then they get really advanced, they fixated again because they’re convinced that they’re always right.

20. Do you care?

P25: Yeah, I really care! I think that’s a really valuable thing to learn as well...the psychology interests me...the way people do certain things and just learning to get out of those habits. That always really interested me. Also, I think it's just valuable in general so I care about it quite a bit.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?

P25: Yes! I think it helped quite a bit. I think I was kind of...I’ve probably said it loads in a bunch of answers now, but I just do find it difficult to not have the physical thing in front me. I can't actually see it, so it's kind of difficult to see the problem...put it in actual terms.

RESEARCHER: With the mechanisms, it’s something I've noticed with most people's videos that they don't want to break them, and that's nice, but you were quite aggressive with The Lamp one, as in, the second you started, you picked it up, you were twisting it, then you just took the back end off. People were less happy to do that with the other mechanisms cos they don’t want to destroy them.

P25: Yeah I can see that.

RESEARCHER: Once people, especially you, you were quite twisty and turny with The Lamp immediately, once you knew it couldn't break.

C3.26 P26 Transcript

P26: Pair (with P27): DMD 2nd Year

1. How long have you been studying design?
P26: So, I'm in my 2nd year now of Digital Media Design, so almost for 4 semesters.

2. What do you think defines a successful student?
P26: I suppose someone who gets rewarded by their work and they find their work rewarding. Someone with good grades, high QCA. Someone who enjoys what to do.

3. What do you think defines a successful instructor?
P26: Someone who explains everything really well, and makes sure that their students understand. Let's say, in a class or tutorial, doesn't let the class go on without everyone being totally comfortable. A class with good grades, a good QCA would reflect a good instructor.

4. Why did you volunteer for this testing with me?
P26: As you're my favourite lecturer.

5. How do you think the physical nature of the puzzles affected your reasoning?
P26: It made everything a lot clearer, it made it a lot more understandable, what the task was, what to do.
RESEARCHER: Did it?
P26: Yeah, as opposed to looking at it on a screen. Looking at it in person, like when I looked up your website [www.designwisdom.org], and I obviously saw pictures of all of this, I was going "what?" I didn't really understand, but when I came in and it was explained what was it and what you were trying to do, it became a lot more clear.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
RESEARCHER: Do you like puzzles?
P26: Yeah. When I was younger, I loved jigsaw puzzles and...Sudoku, that sort of stuff...so, what do you mean?
RESEARCHER: You're imagining...let's say it's the same puzzle on a board, did the fact that it was physical make any difference to how you felt about it or completing it?
P26: You...were able to engage more, able to try and physically figure it out and move things around to get a better outcome, then if you would if you were just looking at a screen.
RESEARCHER: Why would that make a difference to you?
P26: Cos...learning through doing is a lot more effective than learning through seeing or just looking at something. That's what I think anyways.
RESEARCHER: Do you like it better that way?
P26: Yeah, absolutely.

7. How did "Working in Pairs" affect your thinking?

P26: I suppose I was definitely more affected by what Ethan thought and what he was doing, which I suppose had a bit of a cloud over what I would have done if I was here by myself.

RESEARCHER: Why?

P26: I just...I suppose I didn't want to...I know there was no wrong way to it, but I didn't want to be wrong, or I didn't want...

RESEARCHER: There was! There was solving them, or not solving them! So...what did you mean by that, that "cloud" thing?

P26: What Ethan thought and what Ethan was doing had a major influence of what I was thinking, so when Ethan was going one way with it, I was trying to think more into what he was doing, rather than going my own way and looking to see what I would have done if I was there by myself.

8. How did "Working in Pairs" affect how you felt?

RESEARCHER: What you have been like if you were on your own?

P26: I would've been...working more for my own initiative...maybe seeing stuff...taking a step back and seeing the bigger picture of it all, and see different ways in which it could've been solved, instead of just going by what he was saying.

RESEARCHER: Let's say if you came here with someone less experienced than you, would you have been different then?

P26: Probably, yeah. Ethan had loads of experience with the K'Nex.

9. Would you have preferred Working Alone? Why?

P26: I probably would have liked to have done both, worked alone first, and then if I needed help, have Ethan come in. Yeah, probably would have preferred to work on my own.

9a. Were you comfortable with voicing your opinion?

P26: Yeah.

RESEARCHER: Cos you know him?

P26: Ethan's my best friend and I live with him!

RESEARCHER: I get that general impression from the two of you. Even though...I made notes...it's fair enough to say he was taking the lead, a nice way of putting it!

P26: Yeah, definitely.

RESEARCHER: But it's ok? He's like that with other things too?

P26: We need to work closely together in group projects. He wouldn't always take the lead. I suppose we both have different strengths.

RESEARCHER: Ok, interesting.

[REFERRING TO VIDEO NOTES]

RESEARCHER: You started with The Lamp, you start picking it up and playing with really quickly. You, after about a minute, asked me about how others did. Why was that important to you? Why do you say that?

P26: I asked you how others were doing?

RESEARCHER: Yeah, how others had done. You knew that you were at the tail-end of quite a lot of other people who had had a go.

P26: I suppose, at that moment in time, we were in the dark, we were in the unknown…

RESEARCHER: You had only just started.

P26: Yeah, so I was wondering “did everyone start off like this?” or did everyone figure it out straight away?
RESEARCHER: After about 5 minutes, Ethan removed the centre rod, great! Started building a rather complex trigger from K’Nex. After 13 minutes, you suggested using the flexible centre rod. Ethan picked it up, put it in position, said “no” and put it back down. A minute later, you suggested looking at a clue, Ethan said “no” After another 5 minutes, you pretty much described what you needed to do, and then you did it. You did look at a couple of clues. Actually...after 18 minutes you looked at clue 1, then clue 2, and then straight away you said what to do. But it took another 5 minutes to build it. That’s OK. You moved to The Scarecrow, lots of staring, not so much touching. You said earlier you like the idea of grabbing, but you didn’t...
P26: I didn't want to break anything!
RESEARCHER: Cos you had no problem with The Lamp, and you were wrestling that into position. Why didn’t you...did you think you’d break the other one if you went at it?
P26: Yeah, I was afraid. They're all obviously really well thought out and really well put together I was afraid of breaking something.
RESEARCHER: After a few minutes with The Scarecrow, you turned the mechanism to see it in action, which was really good. You dragged it up to the final checkpoint to measure things instead of guessing, so you were doing that. Instead of you trying to imagine it, you did that. Again, starting building a complex thing from K'Nex. I even had to get extra pieces for him! Only 2 people did that!
P26: Nice going, all the complicated ways around it.
RESEARCHER: In fairness, he did always explain his thinking to you. And then you looked at the clue for The Scarecrow because you only have 3 minutes left, and that's what you did.

10. How did you feel about dealing with physical puzzles in a learning environment?

P26: I suppose the fact that it wasn’t spelled out what we had to do, like “this is what your outcome has to be”, and we had to actually figure it out for ourselves, was kind of difficult, so I suppose...what was the question?
RESEARCHER: How did you feel about it? That if...let's see if this was a module and I’m trying to teach Problem Reframing, and the idea of reframing a problem is simplifying things. So usually in lectures, they say “it’s Ethan’s birthday, let's give the best birthday party ever!” You know him and you think...if he likes parties, we’re done, we’re fine. But let's say...he doesn't like parties and no one ever wants to go Go-Kart racing with him. Then you go “Researcher, you said party. No! The objective it is for him to have a good day. Let's go go-karting!” So that's reframing a problem. The opposite of that is getting fixated, meaning you actually...instead of not getting rid of a constraint, you actually make one up! And you think “that's correct!”, and then you go from that position. But you're not correct, so it's not a good idea. So that would be what I’d say you were having a go at learning, but...explaining it in lectures is OK. What did you think about the idea of having a puzzle that... trying to solve it is a part of learning?
P26: Yeah, I thought it was good.
RESEARCHER: Why? I’ll keep saying “why”, no matter what you say.
P26: I suppose you get to figure it out for yourself, which is quite rewarding. And...yeah, that’s it.

11. How did you feel about your performance with the puzzles?

P26: I thought it was quite poor.
RESEARCHER: Statistically, it...wasn't that bad. Several people didn't solve any. Of the pairs, every pair solved at least one. You did solve 1, as opposed to not solving any. What did you think it was bad?
P26: We obviously only got 1 of them, and we only got halfway through another.
RESEARCHER: You got the hardest one!
P26: We spent a lot of time on that! Maybe if I put my theory of the other...flexible one, we might have got it solved a lot quicker, and would have had more time then for the other ones.
RESEARCHER: You could have saved 10 minutes, yeah.

12. What would you have done differently?
P26: I would have maybe pushed my ideas more.
RESEARCHER: Why did you think they weren't worth pushing, because as it turns out, you were right.
P26: Actually when I looked it flexible one, I didn't really know that was that much more flexible than the other one. I just thought it was the size.
RESEARCHER: Even though you done this! This is like a police interview, for the purpose of the recording, I'm showing them the trainee K'Nex thing. You were right in what you said.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P26: I don't really think it had much of an effect. I suppose, at the time we thought we have time to do all of them, so "let's go in and choose one, and just go from there!"

14. How did the choice element, the ability to direct your learning, affect how you felt?
P26: No, I liked it. It was like a freedom element; you can do you want.
RESEARCHER: How did you feel about the clues? You were 18 and a half minutes of The Lamp before you looked to a clue, and then you looked a 2nd one straight away and then you solved it. How did you feel about the clues?
P26: I thought the clues were very helpful.
RESEARCHER: No...how did you feel about accessing them?
P26: I didn't really mind accessing them. I was open to that...if I was having an issue, the clues were there to tell me.

15. What was your favourite aspect of learning like this?
P26: I suppose the fact that it was hands-on, you're physically doing it, and we obviously don't get to do that much of that in our course. I thought it really cool.

16. What was your least favourite aspect of learning like this?
P26: Some of them are obviously complicated. I didn't like the fact that I couldn't figure it out straight away. It was a bit of a challenge.
RESEARCHER: You don't like challenges?
P26: I do like challenges, but just you think you'll be able to solve it straight away and we obviously couldn't, so it was a bit of a challenge.

17. Did you learn anything useful to you? What?

P26: From your given tasks I learned how to come up with ideas quickly under the time constraint and I learned how to think quickly and how to distinguish between useful and un-useful ideas quickly.

18. Did you learn anything that was interesting to you, and not just useful to know? What?

P26: I found it interesting that that applying challenges to something as simple as K'Nex really triggered design thinking and coming up with design ideas and solutions as quick as possible.

19. Do you think that your learning experience helped you to more fully understand Problem Re-framing?
P26: It suppose it taught me a bit more about it reframing the problem.
RESEARCHER: How?
P26: I don't know.
RESEARCHER: Is it something you find easy?
P26: Sometimes. It depends on the situation, but they were quite challenging.

20. Do you care?
P26: Yes.
RESEARCHER: Why?
P26: That was obviously we wanted the best outcome, we wanted to finish and solve everything. Like it's quite rewarding, so yeah.
RESEARCHER: You're not happy you didn't solve all them?
P26: No! No!
RESEARCHER: Not happy at all?
P26: No.
RESEARCHER: Very bitter!

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P26: Yeah...what's the question?
RESEARCHER: [repeats question]
P26: It makes you think to "think outside the box" and maybe take a step back and look at the problem, look at all the possible solutions and then pick whatever one is right.
RESEARCHER: Can you remember the things that you did? I was reminding you of them, obviously. Can you remember them? Can you remember how you felt?
P26: Obviously, when we figured out, with The Light one, what we had to do that was quite rewarding. But then, figuring out how to do was the next step. Then we made a bit complex thing with the light [The Lamp]. But it worked eventually. Then, with the other one we were making really complex stuff as well, but I suppose the solution was obviously really simple with that one, with the Blu-Tack.

C3.27 P27 Transcript

P27: Pair (with P26): DMD 2nd Year

1. How long have you been studying design?
P27: Nearly 2 years.

2. What do you think defines a successful student?
P27: In Design, is it?
RESEARCHER: It's your answer.
P27: Someone who graduates in something they like, that results in doing something that they like, and progressing and learning from there.

3. What do you think defines a successful instructor?
P27: Whether his students prevail or not. Obviously an instructor wants all their students to be the best they can be, I would say if all students are happy and successful in their own minds, he's done a good job.

4. Why did you volunteer for this testing with me?
P27: I like a challenge. I thought it was a good idea. The idea of having real-life problems, minimised into an office was really cool. I liked the idea that you had a challenge in a time-frame to get something done. How you gave...how you proposed it was that there's a solution to all of them, try and find it. So in your head you knew there was a solution, you just have to find a way, or an alternative way to do that. That's what I liked about it, a bit of a challenge.

5. How do you think the physical nature of the puzzles affected your reasoning?
P27: The "physical" made it a lot easier to wrap your head around. If you told me "there's a lamp that you want to lift up and it's off, and you press it down onto something, onto a frame, it's on". Obviously, in your head, you try and wrap it around and think maybe "there's a button that's on the bottom when you press it down" It's a lot easier to think about the solution as opposed to having in front of you and looking for an answer. So it brought in the thinking with the physical aspect, having to go through a thought process to try and resolve the problem.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
RESEARCHER: Do you like puzzles in general?
P27: Yeah, I do. I grew up, obviously, using K'Nex. I like the challenge aspect, where you could actually make, or take away, something to actually make it work successfully, so there's a lot of practical thinking about it. And is also room for creativity. You can go all about it and it was very interesting.

7. How did "Working in Pairs" affect your thinking?
P27: It was a lot more comfortable where you with someone to reassure you. You had a different mind thinking on a different strand so, like you said about "fixating", if I was fixating on something, they probably wouldn't have been. They could bring me back to reframing "I think we should go this route"
RESEARCHER: In principle, that's what should happen.
P27: What happened really was that...we kinda started both fixating on the one idea. And that obviously cost us a lot of time where we were both trying to wrap our heads around it. Whereas, if we went as two individuals, but as a pair, worked as a pair but looked at it as individuals, it probably would have benefitted us a lot more.

8. How did "Working in Pairs" affect how you felt?

P27: It made me feel a bit more a bit more comfortable...it made me feel that this is a Team Project, where...if I let us down, it kinda put more pressure on us at the same time. If I let it down, it didn't work, I'm bringing down someone else's work as well.

[REFERRING TO VIDEO NOTES]
RESEARCHER: I can see you staring intently at them [the puzzles], so you can clearly remember what happened. So you started with The Lamp, picked it up, you were playing with it. You had the centre rod out after 5 minutes and The Lamp switched on. You started building this rather complex moving-parts trigger from K'Nex. Aisling suggested after 13 minutes about using the flexible centre rod. You picked it up, you didn't like it so you put it back down. You looked at some clues. You ended up building a trigger that worked so that was good. It was just more complicated than it needed to be, but it still worked. You were about halfway through your time when you finished that, so you moved on to The Scarecrow. It was very good that you...even thinking about what you said about using your hands, you moved it into the end position, which is all the counts. So that's easier than visualising it. Started building another complex mechanism and then looked to the clue with 3 minutes left, then ran out of time. The Lamp that you solved is statistically the hardest to solve. That was just a reminder as if you'd forgotten any of it. You didn't attempt The Lift at all, because of the timing. Why did you start with The Lamp?
P27: Obviously from looking at it, you gonna perceive the biggest thing is going to be the hardest thing. So I saw The Lamp, "surely shouldn't be too much to this!" I asked Aisling "will we start here?" she said "yeah, let's start there" so that's our brains works, you go from the smallest to the biggest, thinking the smallest is the easiest, biggest is the hardest.
RESEARCHER: That wasn't part of what I designed! The Lift is by far the easiest, The Scarecrow's in the middle, and The Lamp's the hardest. Several have done The Lift really quickly.

9. Would you have preferred Working Alone? Why?
NO ANSWER
9a. Were you comfortable with voicing your opinion?
NO ANSWER

10. How did you feel about dealing with physical puzzles in a learning environment?
P27: I really liked it. I thought it brought a good practical aspect to it. When you're in the real-world, you're going to be giving actual...you're not going to be given problems, but someone's gonna give you a project for a client who wants "something along the lines of this" You're going to be put into a situation where you have to solve, or create a design idea that suits the client's requirements. So this is a good mock-up, it's...obviously been reframed to the size of K'Nex, and there was a time limit...
RESEARCHER: Yeah I couldn't work out how to get 200 miles an hour acceleration in a safe environment.
P27: It was brilliantly made; it was a great concept. The theory behind it is very practical and very good to understand what you have to do. It's a good minimised version about how things should be.

11. How did you feel about your performance with the puzzles?
P27: Inadequate.

RESEARCHER: Aww!
P27: Obviously...I'm competitive, so I didn't want to use the clues. I wanted to get it on my own obviously. When you have the solution, you look back and go "why didn't I think of that?" I think with the time frame, you're kind of just rushed into thinking fast, thinking straight to a solution and obviously the fixating...if you have an idea, you spend ages trying to build it, trying to make it work. When you figure out it doesn't work you, you've to back all your steps and you get a bit lost.
RESEARCHER You did solve the one that won the Nobel Prize for Physics, in fairness.

12. What would you have done differently?
P27: I would have used the advantage...not really an advantage but used the diversity of the group a lot more, as opposed to both of us going along the same idea, we both should have looked at different ideas.
RESEARCHER: I didn't let you do that!
P27: I know…
RESEARCHER: You mean different ways of doing the same puzzle?
P27: Yeah, so either one of us do...we both do the same idea, but in different ways or...did you say we couldn't...
RESEARCHER: Yeah you couldn't split up.
P27: Yeah I would have done that. We would have taken on the same project, but done our own version of an idea that would work, as opposed to working in a team on the same idea.
RESEARCHER: You were, putting it nicely, taking the lead. Aisling tended to ask and you would acknowledge...you were always explaining what you're doing, so wasn't like you're ignoring her, but she tended to ask and you tended to...not ask.
P27: Yeah, so that would have been because of my knowledge of K'Nex. I would have felt like...I know what K'Nex is. With your little test model, I knew what to do.
RESEARCHER: You didn't even make eye contact with it when you were doing it with your hands.
P27: Obviously that played in...if that was in a real-world application, if I was teamed up with somebody who was familiar with the prospects, obviously I would look to him more. But that shouldn't be the case. Obviously we should have both sat down as if we were both new to it. Her idea would have been just as good as mine, regardless of how much I knew about K'Nex. We both should have showed leadership in that role.
RESEARCHER: You were under an awful lot of pressure. I would acknowledge that while I was trying to make it pressurised, I accidentally got it just right. I had no way of gauging it exactly. I wanted it to be almost impossible to solve all 3, so to force you into pressure. As it turns out, only 2 people out of 31 solved all 3. The 1st person solved all 3. "There's no point if it's going to be too easy", but it was ok.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P27: The choice was...my natural instinct was...the 1st choice, I didn't really mind which to start on, we just kinda gauged the small one, I'm going to guess that's going to be the easiest. The 2 big structures looked a bit intimidating. That wasn't a big factor but moving onto the next one would have been my decision, because I would not like to move on from 1, not having it complete. I would rather complete 1 and not touch the other 2 as opposed to attempt all 3 and fail all 3.

RESEARCHER: Was this choice element, did that...was it a positive feeling? Were you happier with the choice? Would you have preferred if I'd given you the order that you should do them in? For ease of finishing? I would have certainly gone "Lift, Scarecrow and then Lamp".
P27: That would have changed the...probably could have changed the outcome. But my way of thinking would have probably been the same...if told me to start on the rollercoaster [Scarecrow] I would have stayed on that until I finished it. But it gives you a nice free environment if you were told to just work away. You told us what we couldn't do, but you didn't tell us what we had to do. So, that gave it a nice little free environment where you could just relax and do your own thing essentially.

14. How did the choice element, the ability to direct your learning, affect how you felt?
NO ANSWER

15. What was your favourite aspect of learning like this?
P27: The choice was a nice element. You had the choice to use the clues. You didn't say it was bad to use the clues. It was down to you as a person. I...probably wouldn't have put in the clues, because me as a person I would have felt that if I tried for 10 minutes on one and used all 3 clues, I wouldn't have any satisfaction. You'd be in and out after 10 or 15 minutes.
RESEARCHER: After 15 minutes, Aisling suggested looking at a clue for The Lamp, and you just said "no"
P27: I just didn't want to use a clue.
RESEARCHER: Why? Why didn't you want to use one? Giving in or...?
P27: I felt like it was giving in! If you were in a real-world application, and someone said…
RESEARCHER: There wouldn't be clues!
P27: There wouldn't be clues! Someone be like "Here. This is a good idea; you should probably do that!" You're on your own, you have to think by yourself. That's why I wanted to do...I knew the clues were an option and near the end, obviously, I just wanted to know what the answer was, so I just used to clues, but they brought in a different factor to it. The clues could act as different people in a group, at the same. You use a clue, so you shouldn't really fixate on your idea. Clues are there to help but they could also represent other people's ideas. Like Aisling's idea to take out the middle thing, that...was a clue. That could have also been a 3rd person in the group saying "hey, maybe we should take out this?" So it is a good idea, for the sense that you should learn to take things on board while in a group. It's not a bad idea to take someone's idea. You could represent them as people as opposed to numbered clues. This is someone's idea, this is another person's idea, these are all clues on the same level of helping you, but it's your decision whether to use them or not.

16. What was your least favourite aspect of learning like this?
P27: That damn rollercoaster! I'm not really sure. I liked all aspects of it, it was a really good idea, it's all well made. The freedom part was very enjoyable, but not sure if there's anything I didn't really like. It all functioned well, there wasn't anything because it's made out of K'Nex...
RESEARCHER: Would you preferred if it was an hour long? Because I say half the people would have solved all 3 if they'd had another 10 or 15 minutes. There was

several people who did 2 and were minutes away and the bell went. Would you have preferred that?
P27: Not really, because it gives you that time to flick through all your ideas in a pressurised time. If you're given a project and given 5 months to do it, obviously you're gonna get it a well-refined design in the end. But If you're put under pressure, you have to learn to have fast, quick, cognitive thinking so it was a good aspect to switch off from reality and actually use your thought process, as opposed to be given time cos you'll just...nowadays, you'll just switch off...how people's attention span will just relax. If you gave us an hour, we would have drank 5 cups of tea and talked for a while.
RESEARCHER: After about a minute and a half, Aisling asked about how other people had done, because you were at the tail end of it, so most people had had a go. You didn't. Were you listening to my response, or did you care?
P27: When you asked…
RESEARCHER: When she asked "how did other people do?"
P27: I did hear, but I didn't really want to know. Because then I would have felt a bit more pressure. If you told me "everybody got it so far" I would have been "now I have to complete this!" At the end, I'm pretty sure I asked how everyone got on, and it was nice that we started on the hardest one and completed it.
RESEARCHER: I think, by the time you did it, 1 person had solved all 3. It turned out to have been the 1st person, but that's beside the point. After that, there had been a steady run of 20-odd people who hadn't.

17. Did you learn anything useful to you? What?
P27: I felt like I did. I learnt that just because you're familiar with a subject, don't get fixated on...I went for the more complicated route and...I should have listened or...me and Aisling probably should have taken 2 different roads, as opposed to me knowing what K'Nex was, and taking the lead on it. We both should have taken a step back, took our perception [preconceptions?] out of the way, just thought "this is a building. I want to get the fundamentals out" That's what we should have done really, just learn the fundamentals, get it out on paper. I need this, this, and this and have to get it done, then we have to get the fundamentals right first. That's probably what I should have done, but that's the aspect of the idea.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P27: The clue on the roller-coaster, gravity is your friend, or something?
RESEARCHER: "Gravity is your friend, so is Blu-Tack"
P27: That gives you an idea so that gives you an idea and it brings you back then it shoots you into another direction. What I liked about it was the solution was the most simplest thing. It didn't have to be as complex a device or mechanism that did this, it was simplicity, more so where design is heading is just "simplicity is key".

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P27: Doing it, I don't think it actually helped me reframing, but doing it and then learning how to go about it helped me learn about reframing. If you just told me to do it and then leave, I would have been the exact same, thought the exact same about things but the fact that we did it, learned, failed and learned again was the key factor about reframing.

20. Do you care?
P27: Yeah I do. It opens your mind, gives you different routes to ideas, gives you bigger scope on how to think. If you have a very cognitive brain, you solve them all the 5 minutes, well done, but there's always room to learn.
RESEARCHER: You learn, usually more by making a mess of something, far more often.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
RESEARCHER: For example, Fixation.
P27: Definitely. It did, in a lot of ways, because people coming into design, after 1st year of DMD [Digital Media Design], you don't fully learn the process of thinking. Your natural instinct is to think of a solution and stick with that. That's the "fixation" problem that people are having. I just don't feel like that's being a factor that we are being taught. We are taught the process, do the process, you will get an idea. But, our brains automatically think to a solution. You automatically do a rough idea of that process and then you fixate on that idea. In some modules, we work backwards. We get a solution, and we work backwards through the process. But, a lot of things play into factors like that. Like me knowing a lot about K'Nex, obviously I jump to conclusion...jump to a solution and work my way back. But, it's a good way to actually open people's eyes, to say "you need to take a step back and reframe, get your fundamentals and take it slow"

C3.28 P28 Transcript

P28: Single: PDT 4th Year

1. How long have you been studying design?
P28: 4 years. This is my 4th year in Product Design.

2. What do you think defines a successful student?
P28: Someone who's able to get their own ideas across to other people, to explain them properly, materialize them properly, I suppose. There's not necessarily a right design for things, everyone has their own approach to things. I'm referring back to Product Design now, some people prefer sketching to model making. But whichever way you can portray best for you and if other people can understand it, I think that's a successful design or idea.
RESEARCHER: Me staring intently at you but keeping my mouth shut, is because I want you to talk and not me.

3. What do you think defines a successful instructor?
P28: This same thing, that someone is able to teach them and guide them properly. Like you need to know the fundamentals of everything you do, so someone who can explain that in the way so that it's like second nature to you I suppose. Again, getting back to Product Design, sketching, you need to know the basics of sketching in order to sketch,

perspective and stuff. And if somebody can't teach you that then you're not going to be able to do it yourself, so something like that!

4. Why did you volunteer for this testing with me?
P28: Aoife made me! No, only messing! It sounded really interesting. I like those kind of things.
RESEARCHER: What kind of things?
P28: Puzzles, brain teasers and such.

5. How do you think the physical nature of the puzzles affected your reasoning?
P28: I like it, being able to look at everything, but I felt I maybe wasted a bit of time looking at every aspect, rather than...no I suppose it was good to see the run through at first, to see how it worked out. From that you were able to pinpoint the problem areas and then you were able to eliminate them one by one.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P28: I preferred it, because sometimes you can feel like it's all words, all text, it can just take a lot of time to visualise it properly, and just see how it works. So yeah it's good to see it in front of you and get a better grasp on it before you try and come up with a solution, I suppose.
RESEARCHER: We'll discuss a bit about what you did in a little bit.

7. How did "Working Alone" affect your thinking?
P28: Amm…
RESEARCHER: I know a lot of your work will be group work, but your FYP is yours.
P28: I can be quite stubborn, so one of the things with the 1st one I did, I was really annoyed...I didn't want to look at the clues. So, I think that wasted me a lot of time. Whereas if I was working with somebody, it's nice to bounce off someone. I know Meadhbh did it and we work well as a team because we're kind of different Meadhbh is really outgoing and she'd go with the really...not unrealistic, but optimistic approach, whereas I'd be more realistic, so we work together. So, if you have someone like that, it's good, but if you have somebody to similar to you and then you get caught in a rut.
RESEARCHER: Do you think you got caught in a rut?
P28: Yeah, for the 1st one definitely.

8. How did "Working Alone" affect how you felt?
P28: No I didn't mind doing it by myself. I liked figuring it out, but it's just the fact that I didn't want to look at the clues. I kind of got over that by the 2nd round, skipped the 2nd one, and got over by the 3rd one because I realised how little time I had. But definitely...I don't know...proving to myself that I could do it without the clues even though there was no...penalty or anything for using them. I just didn't want to. I don't know why.

9. Would you have preferred "Working in Pairs"? Why?
RESEARCHER: Say, if you turned up with Meadhbh, would you have preferred that or did you like it on your own?

P28: I liked it on my own, to figure that myself. It would be interesting to work in a pair as well to see how other people think, but I did like trying to figure it out by myself as well.
RESEARCHER: For example, Meadhbh did 2 [successfully] as well, but she did The Lamp and you didn't, so you could argue that as a pair you would all 3. It hasn't turned out like that for lots of the pairs, but we'll get to that in a minute.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You start with The Lift. You activated The Lift to see it in action. I might have prompted you on that one so that wasn't good on my part. After only 4 minutes in total, you were suggesting building up from the bottom. So, that's great. You already...you made the jump in reasoning, the reframing, it only took you a few minutes. That you realised you couldn't make the car faster, sorry slower, and you couldn't make The Lift faster. So straight away, 4 minutes. That's great! Then you realised that it would block The Lift, that's fair enough. Then you went back to trying to slow the car down. You said the correct solution out loud at 7 ½ minutes, so that's great. No clues! We'll discuss this in a bit, but interestingly...so you had a couple of goes and you was getting it better and better, longer and longer, but instead of keeping going with that, when it was nearly long enough, you then returned to the "building it up from the bottom" solution. I'm not too sure why. We'll talk about that in a bit. I'm just reminding you. Instead of keeping going with the correct one, you went back to the previous idea. But, you had it done after about 26 minutes, you went to The Lamp. You didn't like The Lamp after 4 minutes, and you hadn't look at any clues. It turns out, from what you said earlier, you can remember doing this, even though it was a while ago. Then you were on to The Scarecrow with 15 minutes left, and you looked at a couple of clues. Interestingly, you laughed out loud when your Lift solutions were almost correct. That was odd, because Meadhbh was stony-faced until she succeeded and then she laughed whereas you were laughing. You wanted to stay with The Lamp, you were getting annoyed as you were nearly getting there. But then you went on to The Scarecrow. You were very good at thinking with your hands, in the sense you were manipulating The Lift, you were leaving it down so you could see it. With The Lamp, you flipped it upside-down immediately, lots of twisting and turning. You had no problems disassembling it, no shyness about that. You had The Scarecrow run the whole way up and you ended up solving 2 of them, which is much higher than average. Average is basically one, so that was really good. That was a reminder even though most people didn't need reminding, it turns out they could remember things. We'll get to each point in turn.

10. How did you feel about dealing with physical puzzles in a learning environment?
P28: I like it. I liked it was on-hand work, working with things rather than sitting down and learning it off paper.
RESEARCHER: Why?
P28: You can just explore and learn more, I think. I feel like you retain more even though you don't realise it, whereas if you're just sitting there, looking at words, they kind of just go in one ear and out the other. Whereas, even if you don't intend it, you are naturally thinking if you're actually working with something. So, I prefer it that way.

11. How did you feel about your performance with the puzzles?
P28: I'm annoyed at myself...
RESEARCHER: You did really well! No, you did, in comparison with other people you did. Why are you unhappy?
P28: I just remember looking at The Lamp afterwards, and realising then that everything was focused through the centre and I was just...if I hadn't had spent as much time with the 1st one [The Lift], I would have had enough time to look at that and realise it. And the fact that I was just too stubborn in the 1st one that I didn't want to look at the clues and I wasn't paying attention to the time so I didn't realise how much time I was losing.
RESEARCHER: The clues wouldn't have helped you for The Lift so much because they were to correct people's thinking if their thinking was wrong, whereas yours was pretty ok. This was meant to be about Problem Reframing, but its evil twin is Fixation. The idea with Problem Reframing is generally simplifying an argument, removing a constraint that's been put there.
An example in lectures would be "It's Meadhbh's birthday, let's give her a party!" And if she likes parties, there's no problem. But, if you know her and know that she's always complaining that no one ever goes Go-Karting with her, then you'd say "No. Reframe. No party. A good day out for Meadhbh. Let's all go Go-Karting with her!" So that's Problem Reframing. If there's no problem, fine, but if there is you have to know what to do. Fixation is the opposite, it's when you...what I would do by saying "birthday party", it's introducing an element that you think is incredibly important. Now, if you're right, you've solved it but if you're wrong it actually makes things worse, because you're basing everything on that fact, when it's not fact. So what did you think about that then? You suggested building The Lift up from the bottom, and then you correctly worked out it would get in the way. Why did you return to it?
P28: I think...
RESEARCHER: Several times you added bits and it was nearly long enough, and all you had to do was add one more bit.
P28: I think at that stage when I added in the longer one, I think the car actually got caught...that one time it jammed a small bit and it got caught so I thought that it couldn't go any longer, so then I think I went back to do the lever again, but then I realised that wouldn't work so I went back to the thing and I realise it just got caught.
RESEARCHER: That's Fixation for you.

12. What would you have done differently?
P28: Amm…
RESEARCHER: Would that have ruined it for you looking at the clues? Is it seemed like...
P28: Yeah, probably.
RESEARCHER: If it was a choice between solving all of them no clues or solving them with the clues, would you felt better if you done it without them?
P28: Yeah.
RESEARCHER: Why?
P28: I don't know. I just...
RESEARCHER: This is not uncommon. Lots of people have felt like this.
P28: I always just try to do it without any prompting. I don't know why. I just do.
RESEARCHER: In the real world, you wouldn't have any! But in this case, I'm testing this with 1st, 2nd, 3rd & 4th Years, so the clues are there in case they get stuck. But you saw it as a negative to have to do it?

P28: It's like a challenge.
RESEARCHER: Without looking at the clues?
P28: Yeah.
RESEARCHER: But in the end, when you were short on time, you had no problem. Why did you do it then?
P28: I think it's because I wanted to solve more than 1.
RESEARCHER: So you're not that stubborn then?
P28: Obviously not!

13. How did the choice element, the ability to direct your learning, affect your thinking?
P28: Ammm…
RESEARCHER: You were on your own to an extent, because me giving you less choice is giving you more information.
P28: I don't think I would have started them...worked between them. I think I would have done them chronologically, as I did.
RESEARCHER: How did you feel about having that choice?
P28: I don't think I really thought about it to be honest.
RESEARCHER: I just said "off you go!" Would you have preferred more guidance? As in, me telling you which was statistically the best one to start with. Or would you prefer to do it on your own?
P28: I'm sure if you told me which one was statistically best to go with, I would have started with that. But I was happy with going by myself as well.

14. How did the choice element, the ability to direct your learning, affect how you felt?
RESEARCHER: What about the clues? How do you feel about having them there? I could have written them out a sheet and just had them there, or not called them clues but just given you more information in the write-up. Did you like the fact that you can do it with less help if you wanted, or not?
P28: Yeah, I suppose I saw as a bit of a challenge, even just a challenge get it done with as little as possible, but obviously if you got into a rut, start struggling badly, then to look at them.

15. What was your favourite aspect of learning like this?
P28: Just kind of being able to do it yourself, and figure it for yourself. I like that. I just like doing things.
RESEARCHER: Doing things, as opposed to what?
P28: As opposed to just reading things or looking at things. Being able to fiddle with them yourself, I think works well for me anyway.

16. What was your least favourite aspect of learning like this?
P28: There was nothing I didn't like about it, but it was my own reactions to them. After I looked at the clues for the 3rd one [The Scarecrow], they're actually what I was thinking anyway. So it was just a confirmation of what I was thinking, But then, I don't know if I would have actually follow through with it.
RESEARCHER: Was it annoying that you didn't need the clues because they were to correct someone's thinking if they were going the wrong way.

P28: Yeah it was actually what I was thinking anyway. I was “oh damn, I shouldn’t have looked at them!” But, I looked at 2 of them, I think?
RESEARCHER: You did, yeah. Very good.
P28: I think...and more time!
RESEARCHER: Why would you have liked more time?
P28: I think I would have had a chance of figuring out all 3.
RESEARCHER: I was trying to gauge it to make it really so difficult to do all 3. I was only guessing, but in the end I got it right, cos only 2 people out of 31 solved all 3. But if they had another 15 minutes, about half...15 people would have solved all 3. Though actually, the first person to try solved all 3, so I thought I’d made a mess of it!
P28: Really?
RESEARCHER: But as it turns out another 20 people went by before another person did all 3. It was meant to force you into having to make decisions. But, you did 2. That was very impressive.

17. Did you learn anything useful to you? What?
P28: Yeah. I tend to fixate on stuff big time.
P28: Has that happened to you before, in other things?
P28: Yeah, and I second guess myself.
RESEARCHER: That's even worse, cos the Fixation is usually because of confidence, like you think “this is a thing. Let’s go with it!” You second guess yourself too?
P28: I tend to…“can I do that?” and if it doesn’t work after a while, even if I nearly know that's the right way, then I second guess myself.
RESEARCHER: You did that with The Lift. You did both things have The Lift. I was so upset!

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P28: Just that it's good to learn with actual things in front of you, and the options of choices, clues, was good. Nearly even just to motivate yourself to try yourself first and the option is always there if you need. Yeah.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
RESEARCHER: Were you perfectly comfortable with what the idea was before you came in here?
P28: No I didn't really understand it, so this was good to explain it.
RESEARCHER: You had to reframe all of them to get anywhere. You did it with the 2 of them you solved.

20. Do you care?
P28: Yeah I really enjoyed it.
RESEARCHER: Do you like learning?
P28: I like learning new things or learning different approaches. None of our modules would be like this...we have model-making and stuff, but the practical ones would be sitting down and learning stuff. And that makes up a good percentage of our course, so I think it’s good learning that way.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?

RESEARCHER: For example, they [points at puzzles] are supposed to teach Problem Reframing. It crept up on me during analysing that it's accidentally teaching Fixation, or at least presenting it as a bad thing. Because a lot of people came up with good ideas and then second guessed themselves and then went back to bad ideas. Do you think it helped you understand Design Thinking in general? I'm going to say "why?" no matter what you say now.
P28: Yeah I think so...
RESEARCHER: Because they were three real life examples that you were mimicking.
P28: Yeah, because my dad's an Engineer and I can just imagine his approaches would have been a lot different.
RESEARCHER: He would have done The Lift in about a minute.
P28: I feel like for everyone, he would have just, using a real Engineer's approach to it, a real practical, not thinking inside the box.
RESEARCHER: He would have got stuck with The Scarecrow, definitely.
P28: It just goes to show the whole...
RESEARCHER: Are you like him, or do you think differently?
P28: To a certain extent, I'm like him. I'll be talking about my FYP with him and he's really like...if I come out with an idea, he's like "ah, sure that won't work!", but it's not...that's not the idea of it, it just throwing out any idea and then seeing, whereas he's very "if it doesn't work, why would you even consider it?"
RESEARCHER: See, what's supposed to happen is you're supposed to design things, and he's supposed to build them.
P28: Yeah!
RESEARCHER: He doesn't get involved in the "why?" bit.
P28: Exactly!
RESEARCHER: You'd be in charge.
P28: Yeah, it's interesting that way talking to him. I can't even remember what it was, but we had one weekend I can't remember now...but he had a real Engineer's approach...
RESEARCHER: You don't discuss things with Engineers, you give them instructions...

C3.29 P29 Transcript

P29: Pair (with P30): DMD 3rd Year

1. How long have you been studying design?
P29: 3 years. It feels like forever.
RESEARCHER: You worn out?
P29: Yeah.

2. What do you think defines a successful student?
P29: Somebody who works hard, and...I think after my internship with SAP, I learned a lot more. So knowing and learning along the way...looking back from what I learnt from 1st year to now, when I look back on that I can see what mistakes I made...realising what you did wrong and learning from that.

3. What do you think defines a successful instructor?
P29: Somebody who teaches you.

RESEARCHER: That'd be nice.
P29: And talks to you and takes time to explain things. Because if they can't explain it, then how's the student going to be able to learn it?
RESEARCHER: When I asked the question, you're thinking of specific people?
P29: Yeah. Throughout the years, not just this year.
RESEARCHER: So when they explain it and you're clear, you're happy?
P29: Yeah. When they take time with students to be able to teach them and if they're having struggles to be able to give a little more time and be a little bit clearer.

4. Why did you volunteer for this testing with me?
P29: Cos I like you.
RESEARCHER: Do you like puzzles?
P29: I definitely think it was a good way to able to learn differently, rather than just sitting at a board, looking at...
RESEARCHER: Do like puzzles in general?
P29: When I was younger.
RESEARCHER: Yeah. Not so much anymore?
P29: I don't know; I just haven't had time to do it.

5. How do you think the physical nature of the puzzles affected your reasoning?
P29: You have to work it out, you have to use your hands, use your mind physically to be able to work it...rather than just sitting at a board and trying to figure it out. I think it was a lot better as well, because you're then able to...you have to solve it rather than just looking at it, you have to solve it, you have to figure out what's right and wrong in it.
RESEARCHER: Why did you have to?
P29: Because it won't be resolved otherwise.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
P29: It was a little bit more stressful.
RESEARCHER: Why?
P29: Because you're not just sitting there looking at it, you have to get involved in it. But I think it was a lot more beneficial as well, because you're able to learn from it, rather than just sitting in class and hearing them speaking to you rather than...speaking at you rather than to you. Whereas in this way, you're completely involved in it and it's up to you. It's not up to someone else to be able to teach you. It's up to you to learn from the puzzle.

7. How did "Working in Pairs" affect your thinking?
P29: You're not reliant on yourself. I think if I worked on it by myself I might have been a little bit better at it, because you don't always have to consult with somebody else "what you think about it?" I know teamwork is obviously a good thing, but sometimes working on your own is also good because you learn from it.
RESEARCHER: The success figures for the pairs are better, now you'd expect that to happen because there's 2 people, they are better. So, that's what...you were concerned with, that you'd have to explain yourself.
P29: Even though I feel like we did work well as a pair, at the same time I didn't have much time to think about it on my own. I know you should be more hands-on and just

work with it rather than think about it, but I'm always thinking “what are they thinking? How do they think it'll work?” Then your conscious of your...well not that I was, but people might be conscious of their thoughts on it and thinking “if I say this now, to see if this works, they might think that's stupid, that's not gonna work” whereas if you're on your own, you have to figure it out, you’re not reliant on someone else. Even in team projects throughout the years, I'm always find I work better sometimes on my own, because relying on other people isn't always great.

8. How did “Working in Pairs” affect how you felt?
P29: A little bit more stressful. I know people might think it's more comforting, but I found it stressful because I'm always thinking about what they think...I might just work better on my own.

9. Would you have preferred Working Alone? Why?
P29: Possibly. But at the same time, I don't know unless I do it myself. You don't know unless you’re in the situation, which you’d feel better in doing.

9a. Were you comfortable with voicing your opinion?
P29: Yeah. I don't mind.
RESEARCHER: Would you have been comfortable if you're been with somebody you didn't know so well?
P29: Not necessarily either, I don't know.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You read through The Lift scenario, you activated it, let it run to the bottom to see how it works. You worked out very quickly, the pair of you, what to do. You ended up solving it.
P29: We just used a bigger, thicker thing to begin with.
RESEARCHER: Yeah, that was a problem.
P29: And that's what I'm saying. If I was on my own in that situation, I probably would have figured it out a lot quicker. I don't know. I just feel like...I don't even have an explanation of why.
RESEARCHER: Well you knew what to do. This would be reframing’s evil twin, “Fixation”. Because you started with thicker pieces, and it just took you ages to get off that. That caused a problem. But you eventually did it, but halfway through the time. Then you moved to The Scarecrow. After 5 minutes, you started looking at the clues every few minutes. And you did solve it, and you did do a lot of fiddling with your hands, which is a good thing, because it's an extra way of figuring things out.
P29: I think understanding the question was...confusing for us.
RESEARCHER: Well that was part of it as well. All of the situations were impossible to solve, if you didn't change things. So, you did...it’s the same with design that you end up being hired to create a solution. If it was that simple, they wouldn’t have bothered hiring you. So it's always confusing. You did really well. A lot of nervous giggling, oddly enough, when I was watching the video back. Lots of [laughing noises] from the two of you. You did very well. You didn't go near The Lamp.

10. How did you feel about dealing with physical puzzles in a learning environment?
P29: I think if it was a module, I would 100% work a lot better in it.
RESEARCHER: Why?

P29: Because it’s hands-on. You have to put yourself into it. I said that way too many times now. But, as I said, it’s just...
RESEARCHER: What do you do if it's not? What do you do? Do you just sit at the back and say quiet?
P29: Yeah, because I feel like...even it's interesting, they’re talking at you. Whereas even if it's not interesting and you doing something, it brings a bit of fun to it, because rather than just sitting there...it’s like being at school again, people are...talking to you. You’re not interested in it, you don't care, but you have to do it. But with this, it was a bit more fun to it... because you’re involving yourself in it and trying to solve something hands-on.

11. How did you feel about your performance with the puzzles?
RESEARCHER: You did above average, even for a pair. You solved 2 of them.
P29: Terrible.
RESEARCHER: Why?
P29: Because I feel like I would have...I think time was definitely a stressful factor in it. If we didn't have a time limit, we probably would have worked better. But, then that’s again...if you're working in a team, working on a project in a company, you always have the time. Again...time probably is a benefit to it, because it brings it back to when...from working now in college to working in the future, you learn then that time is always on you. So it does help.
RESEARCHER: Was it there the whole time, in the back of your mind that there was a tick-tock?
P29: 100%, because that’s why I think that's why we didn't work as well, because it’s always “how much time do we have left?” But we probably would have worked better if we didn't have that time there.
RESEARCHER: Well, only 2 of 31 people solved all 3. I imagine, if there had been another 15 minutes, half the people would have solved all 3. That was...deliberate on my part. I was hoping for that, I had no real way of knowing that I judged it right until it happened, but it was meant to force you to make decisions.

12. What would you have done differently?
P29: Done the other puzzle! I think, especially on the 1st one [The Lift] not jump straight to the answer, even though we knew the answer, but still try and figure before...I know you even said “try and see if it works” but even if...then again...thinking too much about it is...doesn't help until you try it.
RESEARCHER: The absolute problem with The Lift was you started with the thicker pieces, and it is designed to not work if you do that. No one's managed to get it to work with the thicker ones, because there’s a problem matter what you do. It either pushes the elevator, or it’s too heavy and it doesn't acceleration from itself enough so that the car ends up trapping itself cos it falls too slowly.
P29: I think that if you hadn't given us that hint, we would have gone straight to the drawing board.
RESEARCHER: I was being careful to not tell you...I didn’t want to use the word “thin”, but I was trying to drag it out of you, the reasoning.
P29: I know I'm over frustrated, but I think of you didn't tell us, then we would have come straight back with “that’s not a solution” For me, that’s what I would have done. I can't speak for Paula.
RESEARCHER: A few people...did what you did and eventually figured it out. None of the clues would have actually have helped with that specific problem.

13. How did the choice element, the ability to direct your learning, affect your thinking?

P29: As in, use clues and that?
RESEARCHER: Or decide where to start, and you didn't have to complete the thing to move on to the next one. I could have made it a rule where you have to do The Lift first, then The Lamp and you can't get off The Lift until it's finished. I could have done that, but I didn't.
P29: Did you start the timer before we decided?
RESEARCHER: I started the timer as soon as I said "off you go!"
P29: And then we decided which one.
RESEARCHER: That was up to you.
P29: That's just making decisions on the spot.
RESEARCHER: Did you like that bit?
P29: Yes, and no.
RESEARCHER: What did you like?
P29: You have the freedom to pick what you like. But, at the same time, there's just too many options, where do you start? What do you choose? Once we had her mind set on it, it was fine, but it's just everything's there, staring at you and it's "where do I start? Where do I go?" and then again with the clues, for me I did not want to look at them, it would have felt defeated if I did look at them.
RESEARCHER: Why?
P29: Because I feel like I can solve it on my own.
RESEARCHER: You did with The Lift.
P29: And I think...I don't know if that's just…
RESEARCHER: The 1st two clues with The Lift were to help you realise that you couldn't speed up the elevator or slow down the car.
P29: We didn't look at them!
RESEARCHER: You didn't look at them because you are almost instantly worked out what you had to do. Actually, they would have been no use to you because there were helping you to work out what you'd already figured out. You did look at them for The Scarecrow. Why did you look at them?
P29: The time. 100%. I knew we were under time.
RESEARCHER: You were. Yeah.
P29: And that goes back to…
RESEARCHER: You preferred the idea of looking at the clues rather than failing?
P29: Yeah.
RESEARCHER: Were you thinking of it as failing?
P29: Yeah...I know we had a talk about "don't be afraid to fail"...I don't know if it's a personal thing or...
RESEARCHER: It is.
P29: ...a thing in general?
RESEARCHER: People have had slightly different attitudes about it, but not too many. A lot of people felt that using the clues was giving it.
P29: I think that again with looking for help. If you're working on a project and looking for help, some people might like they're failing because you're asking someone for help, but it's not necessarily that way.

14. How did the choice element, the ability to direct your learning, affect how you felt?

P29: Yeah.
RESEARCHER: Yeah what?
P29: I suppose it's better to have a bit of freedom to it.
RESEARCHER: Why?
P29: Going back to school, when you're younger. You're always been told what to do all the time, whereas now you should be able to choose what you want to do, you should be free to do what you want. But then, if you're working on a project in a team, you do have people telling you what to do, so...I don't really have an opinion on it!
RESEARCHER: You do!

15. What was your favourite aspect of learning like this?
P29: Yeah. Because I got to figure it out for myself rather than, again, someone telling me what to do. And you get to interact with it, and...

16. What was your least favourite aspect of learning like this?
P29: The time! It always goes back to the time and the stresses. Like taking an exam, you always have the time...even with the concepts that you told us to begin with, before we even started it, from your research behind it, I think it's a good thing, because if you bring that forward to future modules, to future students, I think it would definitely benefit them. If I was doing that, I would definitely benefit me in a module.

17. Did you learn anything useful to you? What?
P29: I suppose…
RESEARCHER: Why?
P29: The things with the clues, don't be afraid to look at them. I say that, but looking back, I wouldn't do it again if I had a choice. Don't be afraid to look at them, but at the same time, if I was in the situation again, I would not want to look at them, but then that's a learning process. Don't be afraid to ask for help!

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P29: ...
RESEARCHER: We'll come back to that one.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
RESEARCHER: What did you call it earlier, spreading out or something? Like, removing constraints?
P29: Keeping your mind open.
RESEARCHER: Do you think this helped you to understand that, or were you fully aware about it before you came here.
P29: Slightly, but when you explained it there again, it makes complete sense. Before that…
RESEARCHER: The fact that you experienced that, because you had to reframe them and then you had the "fixation" thing as well. We'll get to that in a moment. For "reframing"...it's something you had to do, cos otherwise you'd get stuck. A machine, I would argue, can't solve any of these because they can really reframe.
P29: But for the 1st one, 100%. Because, as you said, we jumped straight to it. But if we had sat back and looked at it for a bit longer, then there definitely would have been better solution to begin with.

20. Do you care?
P29: Yeah, I think it was beneficial.
RESEARCHER: Why do you care?
P29: Because it helps you in the future, when you go on to do other things...in your work life or in your other modules as well. Give you an edge, onwards in what you've learned.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P29: Yeah.
RESEARCHER: Why?
P29: I just think that it was good to be able to work at it and use it. Rather than...it was a different experience rather than what you're always used to, because you grow up having someone talk to you...talk at you not to you! And put in a situation where it's all on you, in a learning situation, where it's all on you. I definitely learnt that...it's a lot more beneficial for me, I don't know about other people. Going forward, I think it's...you learn that you have to try things out before you jump to a solution, not just keeping an open mind but framing. But in anything, you have to keep an open mind in it, and try things out before you jump to your clues.
RESEARCHER: You're still bitter about the clues, aren't you?
P29: Yes! Even when I walked out of here, I was saying "why did I looked at those clues? All three of them!" It wasn't even just the one! Don't be afraid to ask for help in it, whatever it is.

C3.30 P30 Transcript

P30: Pair (with P29): 3rd Year

1. How long have you been studying design?
P30: 3 years? Or 2 ½. Nearly 3.

2. What do you think defines a successful student?
P30: Hard working. Actually cares about their grades and what they doing.
RESEARCHER: Do you think for a designer that the grades are everything?
P30: It's part of it. Something to aim for, you feel better if you get a better grade. You have to like what you're doing as well, have an interest in it...going to things makes a good student.

3. What do you think defines a successful instructor?
P30: Not shouting at you. Not making you feel like you're stupid. Helping you when you can't figure things out.
RESEARCHER: Do I do all three?
P30: Generally caring what your students, rather than getting frustrated at them when they can't do something.
RESEARCHER: You like that?
P30: That's directed at a certain lecturer who will not be named.
RESEARCHER: Name them if you want! That's your own business!

4. Why did you volunteer for this testing with me?
P30: Cos you're nice and helpful, so I said I'd help you. That's it! That's the only reason.

5. How do you think the physical nature of the puzzles affected your reasoning?
P30: It's just easier to figure it out, because you can see it in 3D. You can actually interact with it.
RESEARCHER: Why is that easier?
P30: Because you can make changes and see how they'd actually work, rather than just thinking of something and saying "oh, I think this would work", you can actually try it out.

6. How do you think the physical nature of the puzzles affected your emotional engagement?
RESEARCHER: Do you like puzzles?
P30: Easy enough ones, ones I can figure out, like.
RESEARCHER: That's important to you?
P30: I get frustrated very easily when I can't figure things out.
RESEARCHER: The fact that it was physical puzzles, did that make any difference?
P30: Yeah. It was fun. If you come in and just showed us something on a whiteboard, I'll be "Researcher, I'm leaving"
RESEARCHER: If something's fun, you like it, and if it's frustrating, you don't. You don't want to stick at it determinedly, you just get sick of it, do you?
P30: Yeah. If it's very frustrating and it's just going nowhere, and I've tried it for ages...yeah, it just makes me a bit sad really.

[REFERRING TO VIDEO NOTES]
RESEARCHER: So, you're working as a pair with Niamh. You read through The Lift scenario, you activated it, let it run. You actually instantly worked out the solution, cos I heard you say it out loud. So that was instant!
P30: Yeah, I thought that was the right thing to do, but then I thought it didn't look nice.
RESEARCHER: But...really? That made a difference to you?
P30: Yeah...if something doesn't look right, I just don't think it is right.
RESEARCHER: You were the fastest person out of everyone to figure it out, cos you just looked at it and and went "we just do this so!"
P30: Yeah I know, but I was just dangling there, wasn't it?
RESEARCHER: It was very impressive. You started building with thicker pieces than you needed to. That was part of the design. If you build it with thicker pieces, it pushes the elevator and it won't work. Which I done deliberately to be mean. It took you 25 minutes to...
P30: I thought they were all the same. I didn't realise that there were heavier or anything.
RESEARCHER: Ok...cos that's why they were all...there in front of you, but you didn't notice.
P30: I thought that was just because they looked nicer.
RESEARCHER: Ok, that's interesting. That's twice that's come up now.
P30: Yeah. I'm...if things don't look right, you know?

RESEARCHER: But, there was a thinner piece. I'll just... [Researcher goes to retrieve the thin piece from The Lift]
P30: I know. I know, we got it eventually, but...
RESEARCHER: The one part of the mechanism that had was thinner...that had to be changed was thinner. You saw everything else in the elevator was quite big and thick. That's interesting that that was a thing. That caused problems until you moved onto the thinner pieces with a bit of prompting for me. Maybe too much, but I was...
P30: See, I knew that's what I had to do, but I thought there was some way that I'd be able to do it that would look better than that. But...it was just hanging there!
RESEARCHER: You solved that with no clues at all. Then you went on to The Scarecrow. You were quite comfortable with interacting with your hands, putting this [the carriage] back and forth and fiddling with it. Some people were shier and just stared, in much the same way they'd stare at a photograph. You did access the clues and you solved it, which was very impressive.
P30: Just at the very end!
RESEARCHER: Just? You still solved it. That was really good.

7. How did "Working in Pairs" affect your thinking?
P30: I'm gonna say I think she slowed me down a bit.
RESEARCHER: Why?
P30: I dunno. I feel like I just knew what I had to do...
RESEARCHER: You did.
P30: ...for each of them.
RESEARCHER: Why didn't you take over so?
P30: Because I was in a pair! Teamwork, you can't just take over when you're in a team. That's the point of a team. I should have done it by myself, I think.
RESEARCHER: It's interesting that you were thinking that. Cos, I was watching obviously and I've watched the video since.

8. How did "Working in Pairs" affect how you felt?
P30: It was easier, I think.
RESEARCHER: Why?
P30: It was more comfortable with it when she was there.
RESEARCHER: Ok. Because you didn't really know what you were walking into. I'd given you a rough idea of it, but you still had to come in, full of trepidation.

9. Would you have preferred Working Alone? Why?
P30: I think I would have been a bit quicker if I'd been working alone. On the 1st one anyways, the elevator one. I don't know about...the other one [The Scarecrow], but I kind of knew I had to cover the barrels anyway, I just didn't know how to go about it.

9a. Were you comfortable with voicing your opinion?
P30: Yeah, but that's just because I know her.
RESEARCHER: Because you're friends. Did you feel like you were leaving her behind if you took over?
P30: No. I just want to let her...
RESEARCHER: Have a go?
P30: Have a go as well.

10. How did you feel about dealing with physical puzzles in a learning environment?
P30: It was very time consuming, it was the only thing.
RESEARCHER: It took the same amount of time as a lecture?
P30: Yeah, but we didn't get all of them done. If we were in a lecture, we would have gotten them all done.
RESEARCHER: I would have explained them all to you, yeah. Which did you prefer?
P30: It's nice to figure it out, but I still don't think it looks alright.
RESEARCHER: It doesn't! It's made of K'Nex, it's not a real elevator.
P30: I know. It just bothers me, things like that.

11. How did you feel about your performance with the puzzles?
P30: I think we did ok.
RESEARCHER: You were very fast. Your mind was, for working out...
P30: Yeah, but my mind to movement ratio isn't great is it?
RESEARCHER: It's made to not look great because your mind is so fast. I would say that this was a reframing exercise. If this was part of a module, I'd class it as "Reframing is positive, you've to remove constraints that aren't necessary, and its evil twin Fixation is when you introduce things that you shouldn't" So your reframing is really fast. That would be a good thing. The thicker pieces would be the fixation, that for one reason or other, you thought you should use thicker pieces.
P30: I just didn't realise that they weighed anything different.
RESEARCHER: And yet that's how physics works...
P30: They're plastic. I thought they're all the same.
RESEARCHER: They're both incredibly light, but one is much lighter...that's why I did it deliberately, because I'm horrible.

12. What would you have done differently?
P30: Probably looked at the pieces that were there on the table...
RESEARCHER: Why?
P30: ...more. Just to see what I had, because we didn't think the cardboard would be the thing we needed, the one with the barrels [The Scarecrow] you know...we didn't...but that's just me because it doesn't look right, doesn't look like it fits there, so...that's my issue is with everything.
RESEARCHER: Fair enough.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P30: I wanted to do them without the clues, but then we were running out of time on the elevator one...
RESEARCHER: Fair enough.
P30: Not the elevator, the other one [The Scarecrow]...it was frustrating the two of us. We just said "we'll go for a clue".

14. How did the choice element, the ability to direct your learning, affect how you felt?
P30: Not really. It was nice to have it there.
RESEARCHER: I could have written out the clues and just had them there on the desk, and I could have told you the order to do things, but I didn't.
P30: It kind of makes you want to figure it out for yourself really.

15. What was your favourite aspect of learning like this?
P30: It was fun. The fact that you made it The Batman, it was interesting really. Better than staring at a screen, for an hour and a half.

16. What was your least favourite aspect of learning like this?
P30: I think the fact that it wasn't made out of something solid, they're all kind of weird pieces just put me off.
RESEARCHER: That threw you off? Was it catching your eye as well? Were you noticing things you didn't like?
P30: Yeah, it must be the OCD in me, I think.
RESEARCHER: It was a distraction?
P30: Yeah.
RESEARCHER: OK. That's interesting.

17. Did you learn anything useful to you? What?
P30: I don't know really.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P30: Not really.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P30: I think I understand it more; I just have a problem with the fixation side of it.
RESEARCHER: Why do you understand it more?
P30: Just thinking of things that I wouldn't have thought "just make that longer" I would have thought it was something to do with the track. I would have thought I have to slow down the car rather than make the elevator faster.

20. Do you care?
P30: I don't know. It's nice, I just don't know, in the grand scheme of my life, if I'll ever remember the time I made the elevator.
RESEARCHER: If you ever become an engineer for elevators, it'll all come back to you!

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P30: It does, but it's still just the fact that it doesn't look nice is just what I stuck on.
RESEARCHER: Did you know you were like that before you came in here? Are you like that all the time?
P30: Kind of. It's just me. If things don't look right, I think they are right, even if they are.
RESEARCHER: Do you think that gets in the way of you designing?
P30: Oh yeah.
RESEARCHER: At the low-fidelity end of design, it's post-it notes and...do you have a problem with that?
P30: Yeah. If things don't look nice, they're not right.

C3.31 P31 Transcript

P31: Single: DMD 3rd Year

1. How long have you been studying design?
P31: 3 years.

2. What do you think defines a successful student?
P31: Someone is willing to apply themselves, practically and in theory. So, learning both concepts and all the practical things that need to be done at the course, and also try and apply it themselves inside the course or outside the course in projects.
RESEARCHER: You talking about yourself?
P31: Of course.

3. What do you think defines a successful instructor?
P31: I think somebody who is able to adapt their teaching to their students, so that it's relevant for everyone, cos, for example, in one of the modules that was meant to be a 4th Year course, that's now been put into our semester now, it hasn't really been adapted very much, cos all the questions are "for your FYP" so the only adaption that's been made is "or a similar project you've done".
RESEARCHER: Did that annoy you?
P31: Little bit. It's annoyed everyone I think. Yeah, someone was able to make things understandable as well using analogies, or...yeah.

4. Why did you volunteer for this testing with me?
P31: Because I was interested in seeing what the project would be like, and wanted to help you out!
RESEARCHER: Why were you interested?
P31: I wanted to see what the design project would be, because I know we've done our own projects, but I haven't really seen any other ones, anyone else's projects outside of my own year, so I was interested in seeing what other design projects would be like.
RESEARCHER: If you were interested in this per se but you hated me, would you have volunteered?
P31: Probably not.

5. How do you think the physical nature of the puzzles affected your reasoning?
P31: I think it was easier for me to see what would work or not, cos with the elevator one, it took me a couple of goes, and it was because I was able to test it out physically that I knew that wasn't gonna work. Whereas, if I just thought it in my head, I probably went with something different then having it physically in front of me, I probably would've...instead of trying to stop it up at the top, I would've tried to stop it at the end.
RESEARCHER: Yeah that's what you started with...and then you realised that the thing you were building would get in the way.
P31: Yeah, so it was being able to see how it actually physically worked that made me think what needed to be changed.

6. How do you think the physical nature of the puzzles affected your emotional engagement?

P31: I think it...when it wasn't working at the start, it was a bit frustrating but then once I knew I was getting somewhere with it, I was much more inclined to keep going because it was working somehow, I just needed to alter it a little bit.
RESEARCHER: Well you solved 2, which was better than most people, but the one you started with was the one you got nowhere with at any stage. So, was that putting you off?
P31: A little bit, yeah. I think...by the time I got back to it for the 3rd time I was overthinking it too much. And the fact that it just wasn't getting through my head then.

7. How did "Working Alone" affect your thinking?
P31: I think if I was in a pair, I would have been less inclined to try out ideas in case they were wrong, cos there would have been someone else there saying "that's wrong!" So, I think working alone, maybe you'd be able to think about more freely and test out my ideas a bit more. Whereas, I would have been the quieter one in the group if I was in a pair, I think.

8. How did "Working Alone" affect how you felt?
P31: I felt in control, but I also felt a bit overwhelmed at the start, cos I wasn't...cos I started with the one I didn't end up fixing. I just couldn't get it; it was making me a bit frustrated. Maybe if someone else was there and they got it that would have been avoided. But then, I probably still would've been frustrated that I didn't get it. That the other person thought up with the idea. Afterwards, it's a sense of achievement because I done it, rather than me and someone else.

9. Would you have preferred "Working in Pairs"? Why?
P31: Ah no. I think I was happy enough working by myself.

[REFERRING TO VIDEO NOTES]
RESEARCHER: You started with The Scarecrow which, as it turned out, you got nowhere with it, in any way. So you got sick of it after 3 minutes and you moved to The Lift. After a couple of minutes, you decided that you're building it up from the bottom and that was good, except it would get in its own way. Then you looked at clues...after 4 minutes you looked at the 1st clue, but you already understood. Then, 2 minutes later...well actually I have down here you articulate the correct solution at 9 minutes and 15 seconds and 10 seconds later, you looked at the clue. But, you'd already said...well, I knew it was the correct one, you didn't!
P31: Yeah!
RESEARCHER: Then, you solved it...it took you 10 minutes to solve it, but you were on the right track... after 10 minutes, you were on it. Then it took you 10 to incrementally…
P31: To see how long I needed to bring it down [The Lift].
RESEARCHER: Interestingly you did...you made the solution from the top, but then when it wasn't long enough, for a few minutes you went back to building up from the bottom again, second guessing yourself. But then your solved it. Then you went onto The Lamp. Your performance with The Lamp is amazing! You looked at a clue after about 5 minutes, and then you just cracked on with solving it. And then you went on to The Scarecrow, you looked at the clues really quickly.
P31: Yeah, think I was a bit fed up at that point.
RESEARCHER: Yeah you got fed up and stopped with 2 minutes to go because you were sick of it.

10. How did you feel about dealing with physical puzzles in a learning environment?

P31: I hadn't really thought about it much before, but afterwards...I thought about it afterwards and I thought it did actually help me quite a lot to be able to physically manoeuvre things. So, I do think...I thought it was a good idea...I do feel like I wouldn't have come up with the solutions if it was on a whiteboard.

RESEARCHER: You claimed to be bad at puzzles at the beginning.

P31: Yeah.

RESEARCHER: With The Lamp...it was probably the best solving of The Lamp out of everybody, in the sense of you almost instantly worked what to do and then built the simplest solution. So that was impressive, but you didn't think you'd would be.

P31: Yeah.

RESEARCHER: Why?

P31: Bit of self-doubt maybe?

RESEARCHER: I was just wondering why. I know it was self-doubt.

P31: Amm...I dunno…I suppose...

RESEARCHER: Do you like puzzles?

P31: Yeah. I like...ever since I was young, I would have liked actual puzzles, but I do like problem solving but just maybe because it was in a testing environment, I felt pressure.

RESEARCHER: Fair enough. Well it is pressurized.

P31: Yeah.

11. How did you feel about your performance with the puzzles?

P31: I think I did alright. I think with the elevator one, that was average, but the light bulb one was quite quickly. But it's the first one!

RESEARCHER: Yeah, you got nowhere with that.

P31: After you said a solution, it made so much sense to me, but I keep going back to it because I needed to step back from it but...

RESEARCHER: The Scarecrow one was one that...less than half solved it as individuals. Most of the pairs solved that one. It was one where there was a big difference when it was a pair. It might have been that if you worked in a pair, you might have solved all 3, but you don't know.

P31: I think I over-thought it. Because I coming back to it, I ended up over-thinking it too much.

RESEARCHER: Yeah.

P31: And then I was trying to make the solutions way more complicated than they need to be.

RESEARCHER: I have marked down on the sheets that if the person didn't solve it...was their thinking correct? No… There was just something about it not doing anything for you.

P31: No.

12. What would you have done differently?

P31: I think maybe I should have stuck at the 1st one a bit longer.

RESEARCHER: Really?

P31: Because I left it quite quickly, I think.

RESEARCHER: Yeah, you got sick of it after 3 minutes.

P31: Yeah.

RESEARCHER: You came back to it…
P31: I came back to it in between each one, didn't I?
RESEARCHER: Yeah, you did. You looked at a clue at 20 minutes, and 23 minutes. Then got sick of it and went to The Lamp, and then you came back. You had seven minutes left.
P31: I think maybe I should have...either stayed with it longer at the start or not come back in between. I think after...because it was my 3rd attempt at doing it and I still wasn't getting it, that's what was frustrating me. Whereas if I'd moved straight from The Elevator to The Lamp, I think I would have been a bit...
RESEARCHER: Do you get frustrated with doing assignments, normal ones?
P31: Like essays rather than assignments?
RESEARCHER: Yeah.
P31: Not really, unless something isn't getting through to my head. If I'm reading papers and I find something particularly difficult, I would probably find it harder to read and get the content out of it.
RESEARCHER: Why did you get frustrated with these? Cos it didn't matter, as such.
P31: I think I'm not good at failing, in general. Just not something I bode well with.

13. How did the choice element, the ability to direct your learning, affect your thinking?
P31: Being able to move around obviously affected the 1st one, because I was able to move on. Then, I thought "if I get the next one, I'll be a bit more clear-minded for this one" and if I'm successful in this one I probably won't be as frustrated with the 1st one. And then, for the clues, I don't know...I was reluctant to take the clues at the start, because I would rather figure it out myself, but I think the choice of having them there and the temptation when I was getting anywhere frustrated, I thought "I might just take a clue and it might help!"

14. How did the choice element, the ability to direct your learning, affect how you felt?
P31: I thought the freedom of being able to choose which one you went to, and not having to finish one make made me felt a little more relieved and less pressured, cause I think I stuck with the 1st one for too long, and I couldn't move on until I finished it, I would've felt really pressured, and probably then thought "oh, if I'm bad at this one, I'm gonna be bad at the next two as well", if I can't get this one after a few minutes. And then for the clues, cos I had a choice to take them, it was...I was maybe reluctant to take them, and then after I took them, it didn't...with the elevator one, it didn't really help because it already figured it out so I was annoyed with myself that I did take it, that I'd opted for the clue even though it didn't really help me.
RESEARCHER: Would it have been more of an achievement to have solved the two you solved with no clues?
P31: Yeah, I think.
RESEARCHER: I'd say, if the clues have been glued shut you still would've done everything in the same amount of time.
P31: Yeah.
RESEARCHER: So you didn't need them. That bothered you then?
P31: Yeah.
RESEARCHER: But you were OK looking them up for The Scarecrow because you weren't getting it?

P31: Yeah, because I was getting fed up with that, I thought it was fair of me to take it at that stage.

15. What was your favourite aspect of learning like this?
P31: I'd say my favourite thing was being able to physically work it out and then see how it actually solved the issue. Whereas, if it was just on a board, you will be just saying "yeah that's right", whereas I actually got to see how it worked and figure it out for myself. Whereas, if I knew I was on the right path, I could keep going, whereas if it was on a board, it's not very obvious to tell if you're on the right path or not without you saying "yeah, that's right". I probably would give up. So, I think being able to physically work it out would have given me more motivation for it.

16. What was your least favourite aspect of learning like this?
RESEARCHER: That The Scarecrow existed at all?
P31: Yeah! Just take that one out! I'd say my least favourite thing was the time constraint, because that really make me feel pressured. I think, I don't even know, if I had loads more time I don't think I would have solved The Scarecrow one, I think I needed to step back from it. But because I knew I was under time pressure, it made me feel pressured to start...I think that's why I would have given up on The Scarecrow because I knew I only 2 minutes to solve it. I didn't think 2 minutes was enough for me. So, I just decided I'll give up now.
RESEARCHER: Only 2 people did all 3 and I'd say if I've made an hour, rather than 45 minutes, about half...there was a lot of people that did 2, and were close to the 3rd when they ran out of time. That was deliberate on my part to force you...to decide how to do things. At least there's that.

17. Did you learn anything useful to you? What?
P31: I think I learned that I...the importance of testing things out. Cos, I know I do a load of user-testing here, but you would think that something would work, and until you test it out, you won't know really. Because with the elevator one, I would have thought the bottom one would have worked, that was my 1st thought. But then, when I tried it out, I immediately realised it's not going to work. So I think in terms of user design, it's actually helped me realise how important it actually is to test out things.

18. Did you learn anything that was interesting to you, and not just useful to know? What?
P31: I don't know...I think it was probably more interesting how I reacted to the situation. I didn't think that take clues that easily.
RESEARCHER: I found it interesting...that you came in explaining that you wouldn't be any good at this and it turned out that you were.
P31: Yeah, probably that.
RESEARCHER: The thing with The Lamp was great, it was very impressive. It was just, for some reason, clear and you just did it and you won your Nobel Prize for Physics!
P31: I tend to do that a lot. People actually give out to me about that. I'm the type of person who'll go "oh no, I know I'm going to fail this!" and then I get an A in it, and everyone will be "oh you knew you were going to get an A!" I didn't really know.

19. Do you think that your learning experience helped you to more fully understand Problem Reframing?
P31: I think so, yeah. I think it was very effective, just because...when I first came up to these, they all looked a bit intimidating. Once you actually try and think around it, I think it showed you that you don't have to over complicate solutions. If you can simplify down it's much it's much easier to solve them. Whereas I was thinking "we're going to stop that car halfway down", whereas the easier option is just to delay it at the start.
RESEARCHER: Yeah, you were...suggesting building something that would take hours to build.
P31: Yeah, so I think that [points at puzzles] would have helped more. If that was explained in a lecture, I don't think it would have been as effective.

20. Do you care?
P31: Yeah.
RESEARCHER: Why?
P31: I like learning new things, especially around my course. So, I think it was helpful in my future.

21. Do you think that your learning experience helped you to more fully understand Design Thinking? Why?
P31: Yeah.
RESEARCHER: Why?
P31: I think it's the same thing as before, to not immediately overcomplicate things and try and simplify it down and think...since we're doing so much user-design...how would somebody who's not, I'm obviously not an Elevator Engineer, how would somebody who's not well versed in that area solve that issue and that often it's possible, but as long as you can simplify it down and think.
RESEARCHER: You did really well, even with the elevator which I'm gonna count as your first proper go, because you didn't like The Scarecrow at all, you triggered The Lift to see it working really quickly, you had a good look at it, you were poking at things. With The Lamp, it was really quick, you had a good poke around, rather than just staring at it.
P31: Yeah.
RESEARCHER: Do you think the mechanisms...why was The Scarecrow one intimidating?
P31: I think it was because it was my 1st one. Because I came in thinking I wasn't good at puzzles, then the 1st one, when I couldn't get straight away, I was "oh no, I'll see if the next one's any better" So I think it's because I did that one first. I think it probably would have been the same if I had done any of the other ones first, that I would have got frustrated with it. I think even if I did The Elevator first, and did The Scarecrow second, I probably wouldn't have gotten so far off the mark with The Scarecrow one. I may not have solved it, but I think I would've been a bit closer, if I hadn't picked that one first.

C3.4 Thematic Analysis Documentation

The Thematic Analysis was approached from two perspectives: primarily ‘deductive TA’, a top-down approach, and also ‘inductive TA’, a bottom-up approach where findings emerged from the data.

General notes were made to ensure the analysis remained aligned with the theoretical foundations of the questions that were asked in the interviews.

GENERAL NOTES
How did they feel? Why?
Were they engaged? Why? How?
How did the physicality of the puzzles affect them? Why?
How did the Self-determined Learning Theory apply?

After the rough analysis was complete, basic phrases that summarized the interviewees’ responses were aligned with the basic definitions of SDL theory and general pedagogic engagement theory. Some of the responses were expected, for example, varied reactions to the physical nature of the puzzles, etc. Some of the responses were unexpected, for example, admissions of self-doubt, etc.

Basic Definitions & Responses
Self-Determined Learning: Competence; Relatedness; Autonomy
Engagement Theory: Behavioural; Cognitive; Emotional; Agentic (Clues)
Constructionism: Thinking with your Hands
Constructionism/ET-Cognitive: Ease of Visualisation/Immediate Feedback/Love of Puzzles

SDL-Competence/ET-Behavioural: Determination to Solve/ Determination to Learn/Pride/Reward/Challenge/Learned about Themselves/Complaints about Existing Teaching Environment
ET-Emotional: Self-Doubt/2nd Guessing/Visually Overwhelmed

ET-Emotional: Investment: Fun, happy, engaged/frustration, disappointment, pressure, stress.
Bitterness/Rage over Fixation/Clumsy Errors, but a much-lessened emotional response to either a reasonable failure or a clever solution

SDL-Relatedness: Only important when providing help solving the puzzles, rather than a sharing of the experience/Fear of appearing stupid/Self-Doubt

SDL-Autonomy/ET-Agentic: Choice is good/relaxing, but less choice/more guidance was also desired

Then, as the distinct categories that could become themes emerged, the relevant quotes were grouped into those categories, as seen below.

Theme 1: The Visual Feedback Loop

Ease of Visualisation

P1: Holding the pieces in your hand helped… I was thinking of it in my head. If I do this, that's how it's gonna go, so if I was holding a bit in my hand, I was thinking what I could do, rather than just sitting down and thinking about it from afar, holding and fiddling with it, it helped me imagine how it could help and work.

P2: That would be easier, as you can't test if you're just thinking about it. If it's something physical, you will have to go and "Can I do this?" and then go and do it, and then it doesn't work out. "Can I just do this?" OK, go do it. That doesn't work out.
The pulling of the train? It's something you can't visualise, really.
Looking at it, from the elevator thing, I could see the elevator, I could see the whole structure of the elevator and the car outside and everything like that. Back then, when it was invented, people couldn't see things from that perspective. So, I think that, being able to see the exterior from such a distance helped a lot in the problem. If I was in the building looking at the elevator, and only being able to see the doors of the elevator, and thinking "how will I do this?" that would increase the difficulty level, being able not to see outside the box, outside the building per se. I do believe having that perspective did help.

P3: It was probably easier, because it's like 3D in front of you, as opposed to just having to almost visualise it in your head. It's easier to like pick something up then just think about picking something up, if that makes sense.

P4: I'm very bad at visualizing things in my head, my spatial awareness and my mechanical reasoning are god-awful, so I feel like it would have made it easier, but then the other side of it is, I feel like in this particular case, cos it was literally changing the building of something, the actual structure, it would have been near impossible to do it in your head.

P5: It's very visual and...it's more logical to think about it when it's in front of you, you can play around with it in your hands. I think it was good. Very interesting.

P7: The physical aspect took that away and you could see how things actually moved, you could see how things were actually put together instead of just assume that the pieces were working as they should, thinking in your head.
…try and adjust your way of looking at it at a different angle, maybe you'll be able to find something new, the physical representation of it, being able to see it from different sides, different angles is something
instead of trying to hold the information in...an imaginary state in your head, it's actually a physical state that you've seen, you've interacted with and you can go back to that memory and be able to remember everything, if you just recall what that situation was.

P8: It just ties back to being able to see what I'm doing and being able to actually touch puzzles themselves. It's just nice to get outside of your own head and think with your hands.

P11: I think it was easier for me to kind of understand it straight off, as it was a physical thing that I could just go to and I could see every aspect
Once I figured out, for example, the first one [The Lift] "ok, this has to get down before that gets to the end", that just made the whole problem straight away, I knew exactly what I had to do, so I found that it was very quick in that way, for me to understand...so I think...does that answer why it affected my reasoning?
I felt like I understood how to...what had to be...how it was solved, but I didn't know how to go about solving it.
The fact that it was a physical puzzle I would find it a lot easier to understand the problem at hand straight away by saying "it's very simple this has to do this"
I felt that to be a lot easier by being able to visualise it and see it in front of me
I find a lot easier to learn from engaging with stuff, and actually...so for example, I'd never pick up a manual for something, I'd try and use it straight away. I think the fact that I can just go and see the problem, rather than trying to think of it or trying to make sense of this, I found a lot easier to make sense of what's been asked by looking at the physical thing.

P14: Whereas a design student should have the capability to visualise something, like a drawing into a 3D realm, if you didn't, it just takes that effort away immediately, and you can almost visualise what you want to do.
Certainly, the tangibility factor's really important. Being given to space to interact with it on a one-to-one basis, rather than staring twenty feet away from a blackboard and trying to figure it out internally.

P21: Definitely I prefer being able to work with something in 3D and move it around. If I have to think about it, especially when you have it in your hands, it's so much easier to think "will this go in here? Will this happen? How will this work?", rather than having to go I see this drawing...you almost have to redraw it in your head as you would expect it to look. Actually having the physical thing in front of you was a lot better.
Just not to constrain myself when I come to an idea, like with the other ones, The Elevator, I was talking to you as I was doing it, and I can see where I could make the changes.

P25: I guess it was being able to physically being able to have it there. I always have problems visualising things, in a way. I visualise something, and the actual thing doesn't come out the way I visualised it exactly.
I just do find it difficult to not have the physical thing in front me. I can't actually see it, so it's kind of difficult to see the problem.

P28: I like it, being able to look at everything, but I felt I maybe wasted a bit of time looking at every aspect, rather than...no I suppose it was good to see the run through at first, to see how it worked out.
P28: I preferred it, because sometimes you can feel like it's all words, all text, it can just take a lot of time to visualise it properly, and just see how it works. So yeah it's

good to see it in front of you and get a better grasp on it before you try and come up with a solution, I suppose.
P28: I like it. I liked it was on hand work, working with things rather than sitting down and learning it off paper.
P28: Just kind of being able to do it yourself, and figure it for yourself. I like that. I just like doing things.
RESEARCHER: Doing things, as opposed to what?
P28: As opposed to just reading things or looking at things. Being able to fiddle with them yourself, I think works well for me anyway.

P20: I liked it. I think that was great, to be able to actually try out how does this thing work and to think about how to solve the problem. Much better than just thinking about an equation.

P16: I didn't realise how much...sorry now, I'll just word this properly...I didn't realise until afterwards how something practical could help me figure out things. The fact that that was practical [points at puzzles], I figured it out way easier than if I did have to sit back and think about it. If I answer a question on paper, I'd put myself in a rut personally, but the fact that I could get up and do it was way better.
P16: I think it did help, because exactly as you said, the fact that you could take it apart and work it whatever you wanted and make it simple and build it back up. That helped a lot for me anyway.

P11: The Scarecrow! I wouldn't have understood that the barrels rolled, unless I'd seen it moving. But if we weren't allowed to move it, then that wouldn't be physical.

P3: I can think better when I can visualise something in the way I see it, if that makes sense?
P3: To test every time, instead of running the motor to see if it would go up and then if it would be hidden, you could just run it up really quickly, test it, see if we could see it. If we could see it, drop it down and try it again.

P17: It's almost like when you're watching a movie at home and you can get up and do whatever you want. If you're reading a book, you can just leave it. Compared to when you're in the cinema when you're sat down and staring at this thing, you're more emotionally attached to it.
The whole thing was interesting. I think the idea being able to move parts and just to answer a question that you don't know what the question is, is really interesting.

P26: Cos...learning through doing is a lot more effective than learning through seeing or just looking at something. That's what I think anyways.
I suppose the fact that it was hands-on, you're physically doing it, and we obviously don't get to do that much of that in our course. I thought it really cool.
It makes you think to "think outside the box" and maybe take a step back and look at the problem, look at all the possible solutions and then pick whatever one is right.

P18: The "physical" made it a lot easier to wrap your head around.
It's a lot easier to think about the solution as opposed to having in front of you and looking for an answer. So it brought in the thinking with the physical aspect, having to go through a thought process to try and resolve the problem.

Immediate Feedback

P1: So that's how I kind of learn, when it's in front of me and I can touch it, and I can play around with it.
Even holding the little pieces, the pieces that are separate that you're meant to build something with them, even holding them, and looking around with them, and playing with them, sometimes I'd put something together and it clicked, "oh, that's how I should do it!", so it was nice to have something in my hands and move it around. I think that helped me a lot.

P4: It's definitely more interactive.

P5: I liked it more it more than being given a sheet and told "you have to do this, you have to do this". It's very visual and...it's more logical to think about it when it's in front of you, you can play around with it in your hands. I think it was good. Very interesting.
you could take apart things first and see that, "ok that doesn't work, put it back together, try something else". You could also see The Elevator, the key to that was seeing how…
whereas if it was on paper, you would be like "where is it! I don't understand", so I think it was way easier to see it while you were doing it and playing around with it and what doesn't work, doesn't work and you know that.
Seeing it visual, right there, you can change things, you can mess around with things, gets you in the flow, this doesn't work, if I do this, this happens, if I take this, if I move this little thing, the whole thing is solved" I think it was really helpful, if that was wrote sheet of paper, I would be like "no, I can't solve it"

P6: you can see them in a physical sense and you can try them over and over again.
RESEARCHER: Why did you pick The Lamp?
P6: Cos it looked to be the least intimidating.
P6: How interactive it is, because I think once you do have it solved, you can see the results immediately, you can see straight away that you've solved it. It's rewarding to see it if you've done it correctly.
P6:I think it goes back to being apply it immediately there and then and being able to see the results of it. I won't ever forget this.

P8: I suppose rather than having to just think things out internally and try to picture stuff, you get to actually see the different components rather than thinking "will this work?", you can hold it up to the other objects and "no, this won't fit". It's kind of nice being able to just see your actual solutions ahead of you, rather than trying to just internalise it.
…if you were just given the pieces and then you turn away and you have to try come up with things, you'd have to internalise everything, try to picture how things worked Yeah. I can remember everything in detail. I probably wouldn't remember that if that just came in a 5 minute part of a lecture, because I would have nothing to tie it back too, so with a strong physical memory, you can remember stuff like that.
It's nice to be able to design something in the real world that you can see exactly how it changes as you do it.
…the whole idea of your being able to see every single element, and manipulate any element you want and see how that affects the entire thing is kind of a nice part of it

P14: The physical nature of it is really good because you can stand there and you can walk around it, you can interact with it and you can engage with it an awful lot more.

P19: Because you can try it, and then fail and then try again, and then fail. It's through getting it wrong a few times that you know definitely "that's not going to work".
So, I think definitely just trying it and being able to do it there was, it didn't waste that much time and you could just figure it out way quicker.
Yeah, true but you could just try it, and then prove it in a second that it's wrong.
[Favourite thing] That you can just try it out, just try it out, like you think something and then you try it out
So, I just know that by trying out, you can eliminate it straight away, it's a lot quicker.

P20: It makes me feel more in control, I suppose.

P21: Each time I added another bit I could tell I was moving forward, another bit more, another bit more and then coming towards the end I was thinking "yeah that makes sense!" I knew that I was going to get it correct.
You can picture it in your head, but you can't always have every variable happen in your head so if you pull it up "Will it be slow? Will it be fast? Will it rattle? Will things move?" When you do things physically, you can see everything that is happening as you do it. So you don't have to try and worry about what might happen.

P3: I suppose that definitely made it more fun and it made it more interactive and it was easier to pick up stuff and look at stuff and see how it was all... what I do by touching, looking getting a 360, a 3D view of it rather than something on a page.
I was a little bit frustrated because some of them I just couldn't..."oh, where am I going to go with this?", but it definitely made it easier that it was something that you could do.
I think it's great, learning with your hands and actually doing it, because I'm definitely more...I learn through doing something, rather than just reading it off a PowerPoint.
P3: Yeah, and being able to re-work something, I feel that there's something static about drawing and it's hard to re-figure in a way that...like you know sometimes you turn something upside down and you're "oh, I get it now!" Like that.

P25: I think it definitely helped a lot more. It affected me because I felt like I could try stuff out that wouldn't work, and I could go back on it.
I think it definitely made me a little bit more adventurous with it, cos I'm not normally adventurous at all when it comes to puzzles or anything like that.

P31: I think it was easier for me to see what would work or not, cos with the elevator one, it took me a couple of goes, and it was because I was able test it out physically that I knew that wasn't gonna work.
Yeah, so it was being able to see how it actually physically worked that made me think what needed to be changed.
I think it...when it wasn't working at the start, it was a bit frustrating but then once I knew I was getting somewhere with it, I was much more inclined to keep going because it was working somehow, I just needed to alter it a little bit.
I thought it did actually help me quite a lot to be able to physically manoeuvre things.

So, I do think...I thought it was a good idea...I do feel like I wouldn't have come up with the solutions if it was on a whiteboard.
P31: I'd say my favourite thing was being able to physically work it out and then see how it actually solved the issue.
But then, when I tried it out, I immediately realised it's not going to work.

P20: Everything is tangible, and you can try out the mechanism to see how it works and try to develop the topic and how it works and what should I do to reveal the puzzle.

P16: I found myself coming to terms with things quicker, and figuring out things quicker just because I could move them around.
I think I answered that in my last question really. Just being able to actually do it and not sit and stare at it and not put yourself into a rut made so much of a difference in my opinion, for me anyway

P11: I work better by figuring out things with my hands...practical.
I'd find it out quicker by messing with it then actually viewing something over and over again to get it.
Yeah, I think that practically solving problems is probably easier than looking at a page and reading it and then trying to think about it, how to do it. Actually physically having it there and seeing it and playing with it and being allowed to do that makes it easier for your brain to comprehend.

P3: I think I'm a better thinker when I'm touching stuff.
P3: Just the physical aspect of being able to think it through. I said about testing the car, instead of having to visualise it, which can be difficult with things like that…"there's trains and a track!" and it's like a maths question, and I was get lost in them, and can't think any further past!

P17: you can see your results immediately as well.
And actually learning and again, having an end product makes all the difference. Seeing what you've done makes a massive difference. It's not like when you're handing up an assignment, you've to wait two or three months before you get an answer from it.
I remember when we were using the barrels, trying to find ways about it. I was able to test it a lot quicker than me just thinking about it and writing it down. So that's really good!

P26: You...were able to engage more, able to try and physically figure it out and move things around to get a better outcome, then if you would if you were just looking at a screen.

P30: It's just easier to figure it out, because you can see it in 3D. You can actually interact with it.

P30: Because you can make changes and see how they'd actually work, rather than just thinking of something and saying "oh, I think this would work", you can actually try it out.

Theme 2. "I wanted to have them, to see them complete and know that I'd done them fully": A Determination to Solve

Determination to Solve

P1: I was more involved in it, and I wanted to get it finished, I wanted to solve them and I was kinda excited by them.
P3: I would've definitely spent 5 minutes with each, and then been like "whichever one is the easiest, get that one done."

P4: [Dalén Lamp], because objectively that was the easiest one

P5: whereas when I'm left to do it myself, you feel more responsible or something, like this is all on you, so everything you do will either work or not work, so it's a bit more pressure maybe
P5: OK, my main goal was to solve all of them, so I'm gonna use these [clues] if it means I'm gonna solve it quicker. So that's why I jumped to the clues. [Clues Section]
P6: I think, cos they were physical, I wanted to have them, to see them complete and know that I'd done them fully

RESEARCHER: Why were you getting so stressed?
P6: Cos I couldn't do it. I wanted to solve them all, and I couldn't do it. The least favourite thing was how obvious it was, to solve.
P6: Cos it's much different to having an instructor telling you what to do, because you have to do it yourself, so you are forced to come up with the solutions without being told how to do it. Independent thinking and stuff like that.

P11: Well I think I had a bit of an emotional, competitive side going into it because I wanted to complete everything
The 2nd one, overthought everything, got a bit flustered and kinda just didn't get in the end, I ended up over thinking. If I had told myself "just take a step back and see what exactly needs to be done", I think I would have solved it, and the last one was...

P12: The fact that I actually physically seen and had it here, it would have been a lot more involving of me if it was this [points at puzzles], rather than a puzzle on paper.

P19: I think I wanted to try it first without them, but I knew I had a time constraint, and I'd rather a bit of direction, so I looked at them then.

P21: A successful student is somebody that can set a goal and generally attain it, work towards something, actually make it work. A good student might be diligent, might work hard, but a successful one is someone that can achieve what they set out to do, I think.
Yeah, again just the fact that it was physical, it was like a challenge that was standing right in front of you.
P21: When I got that final clue at the end, and I realised "I'm so stupid!" because it only took a second, immediately I saw that clue, I was "OK!"

P25: I guess I just thought "Which is the one I think I can solve the quickest, and which is the one that I can solve the longest?"

P15: As you said, we talked beforehand, doing something, making it wrong, redo it again, redo it, redo it, redo it, redo it until you get it right. It's like you're in a lecture, you've a test,
you're studying at home, you gonna keep at it until you get the right answer. That's really what we did.

P3: I was much more determined, I would say. To actually get it, to solve it. Like I feel like if I was sitting down... figure it out. Because it's there in front of me and I'm "I need to get this done!" and being able to play with it and re-work it.
P3: Because I was "oh no, which one will I pick?" I guess you're like "ok, I should pick the one that's easiest to start off with, go from easy to hard, get them out of the way!"

P27: I really liked it. I thought it brought a good practical aspect to it. When you're in the real-world, you're going to be giving actual...you're not going to given problems, but someone's gonna give you a project for a client who wants "something along the lines of this" You're going to be put into a situation where you have to solve, or create a design idea that suits the clients requirements. So this is a good mock-up, it's...obviously been reframed to the size of K'Nex, and there was a time limit...

P29: Whereas in this way, you're completely involved in it and it's up to you. It's not up to someone else to be able to teach you. It's up to you to learn from the puzzle.

Determination to Learn

P1: I was interested, as soon as you said puzzles, I said "yes". I want to do this and I wanted to see if I'll be able to do it with my knowledge of design.
Thinking back on doing it, I don't remember what you said to me, you know the 5 minutes you talked, I don't remember anything, but to this day I remember what the puzzles are, how they work, and the meaning behind them, why they're there.
I think it'd be more it [reframing] be easier for me to understand to do it, like apply it in the real world, so I think it did help, yes.
I do care, cos this is gonna be, design, I want to work in design I think it'd be important to know any little bit of that, so yeah.

P2: making mistakes are better than succeeding, sometimes.
What I found useful was that when you showed me afterwards, saying that these actually related to real-life problems that happened, were solved by these people who won Nobel Prizes that was my most interesting part that would have been it. Knowing that I solved a puzzle, like come on I'm 22 years and you're in your 40s. It's the achievement of it.
Because if it's a learning experience, you need to learn so there's nothing which will be taught to you in the future will help you now.

P5: it's more memorable because it's more fun and engaging.

P7: Always has questions, always been learning...it's just boring otherwise.

P14: I came out of it having really enjoyed it, and came out of it then thinking about the problems after I left.

P20: Because I'm very curious about research
Well, if I did well, I'm good at design, so that's given me confidence that I'm studying design.
I was saying my antenna was out, I knew there was going to be cues in something you were saying.

P21: Oh yeah definitely, it's just a really creative and fun way to learn
It's a challenge, it's a puzzle. It kind of defeats the purpose if you're taking out the answer as you're working on it.
…and then in that case it's not a challenge, it's not even a puzzle. It's pretty much back to rote learning
It's not so much giving in, as...taking the fun out of it.
So I was thinking at The Scarecrow as an intelligent person that could look at the trailer and be like "there's something obstructing this" or "there's something here!" and that's why I initially went with take the barrel out, so it's not something he could ever think "there's something hiding there" and then when I realised he said "hide", it doesn't have to be visible, it was just so much simpler.

P25: I don't think I would've...enjoyed it as much or learned as much, because I feel like that would be giving you the answer straight away, whereas the fact that I was free to figure it out myself was a lot more beneficial, to me at least.
Yeah, I really care! I think that's a really valuable thing to learn as well...the psychology interests me...the way people do certain things and just learning to get out of those habits. That always really interested me. Also, I think it's just valuable in general so I care about it quite a bit.

P9: I think it made it comprehend more better, then just reading about it.

P10: So, it was good experience I think because I actually learnt something at the end of it, by playing!
But, it makes you think in different ways and apply it also in different ways, so there's no 1 particular way of doing things, but when you learn something here can be applied in a very useful way and it's a phenomenal thing to be a solution to something else. That was an eye-opener for me on the design thinking perspective, but I still haven't done anything much on the lesson that I've learned. Actually taking it and applying it, I don't know if I'm doing it at all.

P11: Yeah! I love practicality! I love it! I love standing in front of something and solving it. That's how I work. I don't like reading a page of questions like this. It all goes like a blur.

P17: Doing anything is different to just having someone tell you about how to do something.
Yeah, you would, because it's an experience rather than sitting there listening to someone else talk about an experience that you didn't have, whereas if you experience it yourself, you're like....
I want to succeed, so even...regardless of if no one else is doing what I'm doing, I still want to succeed. I want whatever I do, to do well in it.

Pride/Reward/Challenge

P1: A little challenge. If I don't finish it, it would be kinda sad.
I was happy that I finished them all. Like the time, the way it was ticking, it making me feel really excited, but I think that's just my competitive nature.

P5: It's cooler when you come up with it yourself with no help.
I kinda wanted to do it without using them, just to see how far I would get.
It's a bit less exciting, less satisfactory at the end when "oh I've done it, but I used all the clues to help me out"
my favourite aspect was that I feel like I was more, I understood more, I understood the solution to all of them, I wasn't left confused or I didn't know the answer and it would wreck my head for the rest of the day.
It's way easier to understand the concepts.

P8: I suppose the main thing is the reward at the end when you solve it is great because you actually get to see the finished structure

RESEARCHER: You solved The Lift with no clues. Well done.
P14: Yes!!!! I don't want to use the word "engaging" again, but a lot more engaging.

P19: …but I was happy with it, even the last one [The Lift], even though I did it the wrong way round, I kinda had the right idea nearly.

P21: Because I heard there was puzzles and I like a challenge.
It's not so much succeeding, as it is "rising to the challenge" that's important to me.
So, maybe using the hints more often would have been better, but even so I still wouldn't have used them that much at all, if it was an option.
Because you're involved in it. It's because you gave me that to solve, I could almost understand the way the guy was thinking as he built it. Because it was literally "how do I get the solution to this problem?
I've been able to work there by myself really helped me understand it a little better.
if I'd gotten the last one, The Lift, or even the 2nd one [The Lamp] by accident, I would have I asked you if you could let me redo it again, because I would have hated the fact that I got it by accident, it's pointless.

P3: You don't have to do everything by yourself, so was kind of nice to have that option. And then...but the fact that it was an option and I didn't have to use it for the last one kinda made me feel a little bit better that I was actually able to figure it out by myself as well, without having to use the clues. [also in Clues]

P25: Because...it's just like you feel like you should do it yourself, the whole puzzle without the clues, just keep going until you have it.

P28: It's like a challenge.
RESEARCHER: Without looking at the clues?
P28: Yeah

P28: I'm sure if you told me which one was statistically best to go with, I would have started with that. But I was happy with going by myself as well.

P10: About that, I think I'm happy that it actually happened, because I would have maybe given in faster and then seen the clue and then maybe still not figured it out. So the fact that we actually can solve at least one of them without looking at the clues did make me happy at the end of it.

P16: I just want to get stuck in and try and solve it myself. I'm stubborn like that, I suppose.

P11: No I'm stubborn like that. I'll keep going until I try and solve it myself.
RESEARCHER: Why didn't you look at them straight away?
P11: Because I wanted to figure out every possible way of doing it without looking at the clues first.

P24: Seeing that...when we pushed down on The Lamp, and the light came on, "this is amazing!"

P28: I do like challenges, but just you think you'll be able to solve it straight away and we obviously couldn't, so it was a bit of a challenge.

P27: The choice was...my natural instinct was...the 1st choice, I didn't really mind which to start on, we just kinda gauged the small one, I'm going to guess that's going to be the easiest. The 2 big structures looked a bit intimidating. That wasn't a big factor but moving onto the next one would have been my decision, because I would not like to move on from 1, not having it complete. I would rather complete 1 and not touch the other 2 as opposed to attempt all 3 and fail all 3.
I...probably wouldn't have put in the clues, because me as a person I would have felt that if I tried for 10 minutes on one and used all 3 clues, I wouldn't have any satisfaction. You'd be in and out after 10 or 15 minutes.

Learned about Themselves

P4: I learned quite a bit about myself, actually.
About myself, it was interesting to see, looking back, how I handled myself.
…being beaten by pieces of plastic...I was very interested how I enjoyed it

P5: So I think I've learned not to be put off. "This isn't bigger than you, you can actually do these things!"

P7: I've read books about it, listened to talks about it. You could lecture about it, you could lecture about it all day and then it comes to down to making that thing that's fun, and all of a sudden, I'm struggling. Very true, very telling.

P19: I think just go for it! Just try things out. It's not as if...if you got it wrong, it's the end of the world. Just keep trying and you might get to the answer.

P25: I learnt a bit about myself, in a way. That I'm not completely silly when it comes to those things, the actual physical puzzles. I learned...I also learned about the examples you gave, actually interesting. The Formula 1 thing was really interesting to me. I'd never heard of that before. I thought that was...very interesting.

P16: About myself, I learned that I need to stop putting myself down and being...and be more confident and just go for it, you're not to say wrong answers.

P11: I learned that I'm actually not half-bad at puzzles.

Love of Puzzles

P1: As soon as you said puzzles, I said “yes”.

P4: I was like “puzzles? That sounds interesting, I’ll give it a go”.

P21: Because I heard there was puzzles and I like a challenge.

P26: Yeah. Because, kind of because it was K'Nex.

P3: Sometimes yeah. I definitely prefer [points at puzzles].

P28: It sounded really interesting. I like those kind of things.

P16: The physical side of things, I like. I enjoy those kind of puzzles.
Those kind of things, I just like to dive in and mess around with it until I get an answer. It doesn't it affect me as such.

P16: it’s really fun, a proper puzzle and you get to do it.
I really like this because I'm more of a practical person anyway, like I’d enjoy Tutorials and Labs, being on the computer and doing stuff. Like for example, in SPSS we’re working out things, so I really enjoyed the practical element of it, because me as a person, I've always been like that even as a child with puzzles...I'd love rather than reading books, I’d be up with my brother making puzzles. So, I just thought it made it easier in my head, when you see it to visualise it, it's just so much clearer and you can go ahead then and do it easier.

The Physicality encouraged Participation/Thinking

P3: Because it forces you to actually think whereas you could sit in a lecture hall and not take anything in. So that gets your brain going in a different way.
Because it forces you to actually think whereas you could sit in a lecture hall and not take anything in.
…you can watch TV but not actually be thinking. It’s that same thing, but you actually doing something, you actually have to think about it.

P8: It just ties back to being able to see what I’m doing, and being able to actually touch puzzles themselves. It’s just nice to get outside of your own head and think with your hands.

P7: the physical nature of the puzzles forces you to visualise solutions a bit more

P14: You've no choice but to engage with the problem in the physical environment, whereas...that's what's done in Labs, but in the strictly teaching sense...

P25: …a physical presence of something is far more powerful to me then something on a lecture slide.

P28: You can just explore and learn more, I think. I feel like you retain more even though you don't realise it, whereas if you're just sitting there, looking at words, they kind of just go in one ear and out the other. Whereas, even if you don't intend it, you are naturally thinking if you're actually working with something. So, I prefer it that way.

P11: It's practical, it gets you thinking. But you're not sitting there falling asleep either.
I'd prefer every single one of our modules to be practical and physical. Like us doing things.
I know exactly how to make them now after doing it, because it made me think and I had the time to do it one time and now I know how to do it.

P24: The Scarecrow in particular, the context around it in terms of design was really interesting. Actually be able to see the Batman and the Scarecrow, and you actually have something there to work with. Whereas if you just said "move this barrel up and hide it from whoever" maybe I would've have been as...excited by it, or interested in it. But the fact that you had an actual context, an idea there, I was thinking about it while I was doing it.

P27: I like a challenge. I thought it was a good idea. The idea of having real-life problems, minimised into an office was really cool. I liked the idea that you had a challenge in a time-frame to get something done. How you gave...how you proposed it was that there's solution to all of them, try and find it. So in your head you knew there was a solution, you just have to find a way, or an alternative way to do that. That's what I liked about it, a bit of a challenge.

P26: You have to work it out, you have to use your hands, use your mind physically to be able to work it...rather than just sitting at a board and trying to figure it out. I think it was a lot better as well, because you're then able to...you have to solve it rather just looking at it, you have to solve it, you have to figure out what's right and wrong in it.
RESEARCHER: Why did you have to?
P26: Because it won't be resolved otherwise.

P26: It was a little bit more stressful.
RESEARCHER: Why?
P26: Because you're not just sitting there looking at it, you have to get involved in it.

P26: Because it's hands-on. You have to put yourself into it.

P27: It kind of makes you want to figure it out for yourself really.

P24: Yeah, and it allows me to explore. So, in a way it allowed me to...I was in the problem when I actually was working with the physical objects, that was me trying to solve something and learning in the process, as opposed to you telling me something. I think I felt good playing with it. It was something that was there, I could feel and it made me feel more engaged, as opposed to just hearing words and maybe just seeing something.

Criticism of other Teaching Methods

P1: there has been so many different modules which haven't been really related straight to design, which is…that's why I haven't thought I started studying design until I went on CoOp.
if the instructor is boring and they just read of the slideshow, sometimes I don't bother, I know it's bad, but I just don't go to the lectures.
I remember everything I was doing and things I was saying, and how I felt. Whereas if you asked me about lectures I had even in the past few weeks, I would have no clue.

P3: I wish, 4 years ago, I started learning design like that. I think I would be a lot more confident in it and probably think differently and think better if we had been taught things like this, the whole way through. But that just makes me sad about my course
I probably feel like I learned a bit more about design in that 45 minutes than I probably have done in most of my design modules, in terms of none of the rest of them have really changed the way I think about things.

P5: I've have assignments where they touch on a part of it in some lecture, and it's really vague and then they say "go and do this" and I spend the first half of my time looking up how to I do this, this and this.

P6: I have a module right now with a girl, she's teaching and she's a PhD student and she hasn't a clue what she's doing.

P8: My pet peeve with instructors are those who read off notes to you, especially in lectures. We can easily read notes ourselves.

P12: That's "problem reframing". It's a difficult skill, because there isn't any specific course dedicated to it, and it's something that I found much more experience in, in the real world than any academic environment really

P14: But it's something that I don't even think about when I'm approaching design problems is "reframe the problem", whereas now I probably will

P28: I like learning new things or learning different approaches. None of our modules would be like this

P19: our instructors are like "that's really bad, that's really bad!", when we obviously go in not having a clue about the course, I don't think that's good instructing.

P21: she obviously I would say she does know her stuff, but because she can't communicate any of that properly, then it's pretty much useless to us. As an instructor,

she's not the best and her inability to make yourself understood just means that she'd be better doing her job in a company or business somewhere, and not lecturing or trying to teach it.

P21: ...not giving out about our Lecturers, but have complaints sometimes when they're doing some things or they don't tell us when certain deadlines are, stuff like that. Even the way they teach us sometimes. They give us one-day-mini-workshops on something, and then they expect you to be experts at the end.
Like whatever they might do in their own careers they might be very successful but actually teaching someone is a lot different. I think it's a really area as well...and Aoife slightly made me do it.

P31: I think somebody who is able to adapt their teaching to their students, so that it's relevant for everyone, cos, for example, in one of the modules that was meant to be a 4th Year course, that's now been put into our semester now, it hasn't really been adapted very much, cos all the questions are "for your FYP" so the only adaption that's been made is "or a similar project you've done".

P15: We're asked questions in class and they just told us "look at your notes" and that was it. We still didn't learn anything from it.

P16: I'm in 4th year now and that was something totally different and new. Rather than you having to sit down and think up things and go over it, which I know designers do, that's their job, but when you get to actually go and fix a problem.

P11: For someone has been teaching the same thing over and over again for the last 5 years, to just be like "this is easy!" and then have a few students who just don't get it and just push them to the side instead of actually helping them, because they just can't get it. I don't think that's personally right. I think every student should have an equal chance and an equal opportunity if you're putting in the work, and you know they're putting in the work.

P18: When it comes to something like SolidWorks, we're making a stupid Stirling Engine that's been done every single year, just for the s**** and giggles, I don't appreciate it. In fairness though...if I...I said this when I had my grinds guy for SolidWorks, I said "if I had had the chance to play around with this in my own time, when I wasn't under a time constraint, and I wanted to do exactly what I wanted to do in SolidWorks, I'd love it. Like the Darth Vader egg cup. If I had that project, I'd be "that is sick" I'd love to do something like that, but it was so intense and doesn't isn't really required for the field we're going in the direction of, no. And there's a s*** teacher!

P17: …like [Lecturer Name] who is teaching [Module Title] is brutal because she's absolutely no passion whatsoever! Loads of the lecturers we have are terrible because there's no excitement behind what they're talking about.

P24: Like I said, it's the emotional aspect of it. You just get more attached to it. There's times...I don't know how many hours I've spent in lectures and just falling asleep and not paying attention, even in Labs. And you're just copying and pasting

stuff sometimes. This just makes a massive difference because you actually have to do something.

P27: after 1st year of DMD [Digital Media Design], you don't fully learn the process of thinking. Your natural instinct is to think of a solution and stick with that. That's the "fixation" problem that people are having. I just don't feel like that's being a factor that we are being taught.

P3: Because if they can't explain it, then how's the student going to be able to learn it?

P30: Not shouting at you. Not making you feel like you're stupid. Helping you when you can't figure things out. P30: Generally caring what your students, rather than getting frustrated at them when they can't do something.
RESEARCHER: You like that?
P30: That's directed at a certain lecturer who will not be named.

Self-Doubt

P5: I would say it's very overwhelming, that's one thing I would say, I don't know if it's because the 3 of them are together in the same space and you're like "where do I look, where do I start, what's what"
I would say overwhelming. When I came in first, I was "that looks so hard, I don't anything about K'Nex!"
At the start you're a bit kinda like, oh wow, this is gonna be way too hard for me to do. But it's only when you get into it, it's "ok, I can do this. I can do this." I think initially, the emotional side of things, that's way out of my league, that looks so big...but other than that, it's fine, once you get into it and you know what you're doing, they're no emotional effect. No bad emotional effect!
Yeah, that ties into what I said about the physical nature of the thing, it was so "whoa, I've started off with a really big one and it's so tall and looks so complex"
"wow, I'm never going to be able to solve that", it's probably off-putting, I'm probably getting off on the wrong foot, instead of "this looks like something I can do, let's go, let's go!" This is so hard, my mind-set. Because it looks so complex, so big that's just me, I'm more like "that's scary. I'll never be able to do that" That's what I least liked about it, but literally just me, I think.

P7: It was all very well...it was big and intimidating and well put together.

P13: Yeah if they were on different tables. It is a bit overwhelming when you're up there. There were all sorts of puzzles around.

I think it's more self-thing proving it to myself as well.

P14: I always thought that problem solving isn't a strong point of mine, even though I am kind of logical in the sense of needing to figure out how things work before I'd progress.

P19: Even though I tried not to be, I was like "oh, I need to get this, and if I don't I'm, you know, stupid."

I will still “oh, I can't do that”. So, that was interesting knowing that I stopped myself there.

P20: I did remember a feeling of panic when you were giving me the instructions, cos...I tend...I tend to...I’ve a little voice in my head it says “you won't understand that!” I dunno...I’ve a little voice that says “you're dyslexic, you’re a bit dyslexic, you won’t be able to digest those instructions!
I don't...that I feel prepared in myself. But, I do have that comparison going on sometimes, a bit of an insecurity that these guys are a bit quicker on the uptake than me.
Yeah. I was a bit afraid that if I don't do this, I’m going to be stupid!

P25: I think I would have been a bit more adventurous like that, taking them apart and be willing to try something out that in your head, it seems like a stupid idea but it just might work.

P28: I tend to…”can I do that?” and if it doesn’t work after a while, even if I nearly know that's the right way, then I second guess myself.

P31: I think if I was in a pair, I would have been less inclined to try out ideas in case they were wrong, cos there would have been someone else there saying “that’s wrong!”

P10: I would maybe hesitate much in voicing out my opinions then, because then the factor of being judged would have come into the picture.
I feel fear that maybe she judge me, that “oh, I would have done better if this girl wasn't with me!”

P11: …most of the way I speak with sound like I'm stupid all the time.

P3: Yeah, I was like “it bends!” I completely second-guess myself, I don't know why…
I think I just assumed I was wrong before I even tested it.

Theme 3: “It's been giving me nightmares”: The Bitterness of Failure

Fun/Happy/Engaged!
P1: there was some content behind it, there was a story, because if it was just a simple puzzle with no Batman at the top or anything, I probably wouldn’t remember it as much, but because there was some fun aspects to it. I just enjoyed it. Because when I was explaining it to my mom ”there was a Batman”, it's kind of like a child thing, it was more exciting, I just remembered it more.

P3: And it was also just more fun.

P4: Almost a sense, it sound ridiculous, almost a sense of an adrenaline rush, of using my brain in a different way

How much I enjoyed it actually.
In the end, at the time being beaten by the puzzles was annoying but it was enjoyable, it was fun, almost being beaten by pieces of plastic...I was very interested how I enjoyed it

P11: It was fun and it was different

P7: When you're having a bit more fun, you think more creatively, so I definitely think it frees up a lot of your thought, and it means you're not under as much stress then you otherwise would be.
Very interested. It was engaging, it was a lot of fun.

P3: It was good that it was fun and interactive

P15: It's more fun really, straight off the bat.

Frustrated & Disappointed

P3: I probably would have checked the clues straight away. Just to have them and get going faster.
I would've definitely spent 5 minutes with each, and then been like "whichever one is the easiest, get that one done."

P4: Lacklustre!

P5: I should have stuck with my gut and started with the one that looked less intimidating, cos I thought that when I came in, I was "that thing over there [The Lamp] looks less scary", I should've not wasted time looking at this first [The Scarecrow]
There was a load of annoying things. If I done it again, I do it different, definitely not waste my time at the start.
I was "arghh!" It was so easy but I knew what to do, but didn't know how to do it. It was frustrating, but it was fine. It was fine.

P6: I feel like I could have done better
I probably would have calmed down, like "OK, it's not a big deal", I feel like when I was doing it, I would've looked at it as one big picture, rather than focusing on these things and I felt like I was getting overwhelmed then by focusing on this, and why can't I do this and that this isn't working.

P11: I would have stepped back and I would have thought about it again. I would have gone back to the drawing board, in a mental sense, yeah...that's one of the things I would have definitely done because if...not be...I was stuck on a certain way of thinking

P7: Very interested. It was engaging, it was a lot of fun.
I'm still kind of angry about it because I didn't want to break the thing. I didn't want to break the stand but then it could have worked without it, if you just took out more of the grey sticks...

P14: Disappointed.
I'm very much of the...very much wired in the sense that I need to do one thing then do another thing, then do another thing. I'm not great at jumping from thing to thing, so in that sense, I was disappointed

P21: Good, but a little annoyed.
P28: I'm annoyed at myself...
RESEARCHER: You did really well! No, you did, in comparison with other people you did. Why are
you unhappy?
P28: I just remember looking at The Lamp afterwards, and realising then that everything was focused through the centre and I was just...if I hadn't had spent as much time with the
1st one [The Lift], I would have had enough time to look at that and realise it. And the fact that I was just too stubborn in the 1st one that I didn't want to look at the clues and I wasn't paying attention to the time so I didn't realise how much time I was losing.

P18: I guess I was a little bit disappointed, because when I arrive here, I think "ok, we're going to solve them all" but, then again...it was great. It was very interesting. I liked it.

P15: [expletive]

RESEARCHER: And you didn't like the fact that you didn't solve all of them?
P11: Yeah, that's annoying me.

P24: It's also not being able to get to The Lift is frustrating.

P18: I thought it [her performance] was quite poor.

RESEARCHER: You're not happy you didn't solve all them.
P18: No! No!
RESEARCHER: Not happy at all?
P18: No

P27: Inadequate!

P29: Terrible.

Pressure & Stress
P6: The time, definitely. Yeah, even in a video games, when you get a time trial it's literally the most stressful thing I've ever experienced, it's so bad. If you said "come in for the day, have all day at it", I probably had been less stressed about it, but that would have made no sense to have all day to solve really easy things.
P6: The fact that I could [choose the order] was good cos I had options, I wasn't "OK, I need to get this done before I can even attempt the other ones"

Bitterness over Fixation/Clumsy Errors

P1: Disastrous!

P3: No, not even “giving in”. It was “I should be able to do this! I’ve done 4 years of design. I should be able to do this! ”
Yeah, but I didn’t...
P4: Definitely, fixation was a big problem of mine
I care that I learned that I need to, I know that fixation is something I do in everyday life, so it’s almost having to acknowledge it, it is seeping into my education as well. Makes me realise I might have to deal with it.

P11: I think I was overthinking it, almost. I think I was really kind of...when...it's been giving me nightmares.
Yeah, yeah, still annoying me.
Yeah, the fact that I failed was, now that’s just my own competitive nature.
if I had taken a step back and could have refreshed my thoughts and try to think outside the box, rather than the very set way that I had thought.

P13: I felt let down by myself, I should've done better.
As it was there physically, and had a few other pieces...that’s maybe why I felt inclined to use a few K’Nex pieces. As I was going along, I would almost test myself first.
…it's definitely made me more aware of some of the things that designers could get stuck in, some of the things that will be good if you left out, things I could avoid in the future so I don't get fixated.

P3: I was kind of frustrated! Cos, the 1st one [The Scarecrow], I just didn't understand it at all and I didn't get it, and then seeing the solution I was like “oh, I could have got that!” I was happy with the last one [The Lift] because I actually understood it and got some sort of solution that worked. Kind of annoyed about the 1st one.
I suppose for the 1st one anyway, I should have actually let the car run all the way up to the top, because then I would have seen that the barrels fall down.

RESEARCHER: Why would you have liked more time?
P28: I think I would have had a chance of figuring out all 3.

P31: I think I over-thought it. Because I coming back to it, I ended up over-thinking it too much.

P10: Barely managed to just go to the last puzzle!

P23: With the puzzles? Ok-ish. Not that great.
Once I knew the answer, I felt a little sheepish there, because it was there, staring, staring right into my hand and I didn’t do it.

P10: I didn't manage the time well, so a lot of factors that are there...pointed to me that “you didn't do it! You didn’t do that!” The disappointment. The competition thing!

P11: Because then I would have known what was...the thicker ones that weren't going to work compared with the lighter ones and I should have made that connection, that maybe if it was a little bit lighter, it would help it slow down a bit more.

P23: I am disappointed in myself that I didn't just try that stupid bendy stick in there when I said it, and then I feel like we would have had more time to get all of them done.
I'm still annoyed. I'm actually still annoyed about it that I didn't...

P27: Obviously...I'm competitive, so I didn't want to use the clues. I wanted to get it on my own obviously. When you have the solution, you look back and go "why didn't I think of that?" I think with the time frame, you're kind of just rushed into thinking fast, thinking straight to a solution and obviously the fixating...if you have an idea, you spend ages trying to build it, trying to make it work. When you figure out it doesn't work you, you've to back all your steps and you get a bit lost.

RESEARCHER: You're still bitter about the clues, aren't you?
P29: Yes! Even when I walked out of here, I was saying "why did I looked at those clues? All three of them!" It wasn't even just the one! Don't be afraid to ask for help in it, whatever it is.

Theme 4. "I think she slowed me down": Sharing is one thing. Winning is everything

<u>Comments about relatedness, buts NOT related to efficiency</u>
P7: the co-operative nature of it would have been a lot more engaging, I feel.
That's fine, if you're comparing friends and it doesn't matter as much, because you've self-worth outside of this numerical thing, but when comparing yourself to strangers on a scale of where you are now on an average bell curve, no one wants to be told they're below average
I'm curious to see how they'll do.

P26: Yeah, so I was wondering "did everyone start off like this?" or did everyone figure it out straight away?

P27: It was a lot more comfortable where you with someone to reassure you.
P27: It made me feel a bit more a bit more comfortable...it made me feel that this is a Team Project, where...if I let us down, it kinda put more pressure on us at the same time. If I let it down, it didn't work, I'm bringing down someone else's work as well.
P27: I did hear [when P26 asked how everyone else did], but I didn't really want to know. Because then I would have felt a bit more pressure. If you told me "everybody got it so far" I would have been "now I have to complete this!" At the end, I'm pretty sure I asked how everyone got on, and it was nice that we started on the hardest one and completed it.

P30: No. I just want to let her...
RESEARCHER: Have a go?
P30: Have a go as well.

Comments about relatedness related to efficiency

P1: because I worked alone, it helped me work on my own time and I could move around the 3 puzzles and do everything by myself, do a bit here, but if I don't know what to do next, I can move and jump from puzzle to puzzle, I can make my little mess in my head, work with my hands. I just felt like I have to finish it and I knew it's my own, I don't have anyone to ask questions and to help me, I did have the little clues, but it was kinda like a challenge, and I felt I was challenged that I had to do it, I was kinda motivated by myself.
Otherwise, if it was another person, it would be a mess and we would just end up not finishing anything.

P1: Well, thinking on my own, I felt all my decisions were mine, which is empowering. And also, it's nice to know when everything is your call, which it was. it's just the feeling of knowing that if you make a mistake, it's your mistake. Feel in control

P3: I think it would have been easier because I could have bounced ideas off someone, and if someone had said something it might have triggered for me so it probably would have been easier.
I do think it would have been a little bit easier if there was two people.
If it had been an hour on my own, I would have preferred working on my own, but for the 45 minutes...yeah, pairs probably would have been easier.
If it had been an hour on my own, I would have preferred working on my own, but for the 45 minutes...yeah, pairs probably would have been easier.

P4: if it had been a pair, I would have actually got frustrated with the other person cos I would have realised I wouldn't doing very well, and if they weren't literally dragging me along, that means they aren't doing well either and so then I'm just getting frustrated with them, blaming them.

P6: I think, I imagine that I would have been better working in pairs or in a group. I obviously solved the Batman one and kinda solved The Lift one, but I feel if I'd had someone else there to talk about it and they could see it as well, then more brain power working on the one thing would have solved it quicker.
Probably would have made me feel more comfortable with it because there would have been 2 of us, either 2 of us succeeding or 2 of us failing together.

P8: if I had to go through 4 times the number of ideas, it never would have been done on time

P11: I wasn't having to consider other people's opinions or views on the problems that I was able to focus on my own trying to fix it.
I kind of felt like if you do what I want really, it was up to me. I think, not that there was any pressure or anything, but I felt like there was more...I felt there was more onus on myself to really be motivated to finish it.

I'd be stubborn. I didn't want any help. And then when I realised, I probably realised a bit too late that I needed help, that I wasn't going to solve it without the clues, so I think my own stubbornness came into play there a bit.

P13: A lot more responsibility for me.

P14: working in isolation just means you get bogged down in that problem, and you've no one to communicate it with.
Feel a little bit isolated, a little bit isolated when you consider that you've a limited amount of time...with the time pressure, you could feel like this problem is slightly overwhelming, then you get bogged in it and you can't, you can't get out of it and then you feel pressure.

P19: …you've double the brain power as well, obviously!

P20: It's kind of undistracted because you...it's only your own brain has to understand it.

P21: Especially when it comes to a single puzzle, we can't just work on it by ourselves for a bit and then come back and show each other what our ideas were, we'd both have to work on it.

P3: I suppose I probably would have been a little bit less...not anxious...I would have been...yeah, a little bit less anxious if someone else was there working with me.
[Why?] Because working with somebody else, it does...they help you and encourage you that you are doing it the right way. I, personally myself, I'm very bad at making decisions, being... this is the right decision to go ahead. I'm such a...all over the place.

P25: I was a little bit intimidated, because again because I don't have something to fall back on. You don't have another person there also struggling, so you don't feel as bad about it. Or figuring most of it out on your behalf because they're smarter or better at the puzzles. So, I felt a lot more intimidated, but I also felt a lot more free because I also didn't have another person doing the puzzles with me and judging me and my suggestions so I kind of felt free to do whatever I wanted.
So you've gotta always do one first, so that would take away more time as well. So I think working alone is a lot more efficient, in a way.

P20: I felt very comfortable, and there is another person here to collaborate, to think aloud along with me, so that we might come up with the idea faster than if I'm alone, perhaps.

P10: It helped me in a way, because I think we built on each other's sentences and statements and that's how we applied ourselves to the problem solving, for the first one at least.

P11: If I had done it by myself, I would have played with all of them first to come to a conclusion, and then went and solved them. But with XXXX, she wanted to open the clues.
Walking into the experiment and not seeing...what the experiment was beforehand, [which is] what actually happened. I would have been apprehensive going in and

doing it myself. I would have been a bit nervous and probably put more pressure on myself, but because there's somebody else there, I probably wouldn't have felt as nervous.

P17: I think she hindered me.

P17: Working in a group, for me, is good in some cases, because you get reassurance of what you doing, that what you doing is right. Whereas if you're on your own, you have to self-motivate and make sure you doing everything right yourself. But then you're also more driven to make sure it's definitely right, because if it's wrong, the blame is directly placed on you, rather than split between two people.
Being in pairs frustrated me because I'm usually the type of person who wants to get things my way, and I was fairly confident I knew the way how to do it, and the constant having to explain the other person's questions was frustrating for me.
And I tried to explain how to do them, but I spent so much time trying to explain why I was doing the things I was doing...I think it slowed it down.
I figured the solution at the end, but if you subtracted the time I spent explaining the solutions to the other ones, I'd have had time if I was on my own.

P3: I actually did think a good bit about this one. It's a good question. I think it was a lot better to work in pairs, cos you guys weren't really allowed say anything to us, whereas me and P24 could bounce things off each other. Or he could say something that would spark something and I'd be like "oh crap!" and it would lead onto something else.

P24: I get more into it if it's a pair, because it's just this group mentality.

RESEARCHER: What you have been like if you were on your own?
P26: I would've been...working more for my own initiative...maybe seeing stuff...taking a step back and seeing the bigger picture of it all, and see different ways in which it could've been solved, instead of just going by what he was saying.

P29: You're not reliant on yourself. I think if I worked on it by myself I might have been a little bit better at it, because you don't always have to consult with somebody else "what you think about it?" I know teamwork is obviously a good thing, but sometimes working on your own is also good because you learn from it.
Even in team projects throughout the years, I'm always find I work better sometimes on my own, because relying on other people isn't always great.
I probably would have figured it out a lot quicker. I don't know.
Because I got to figure it out for myself rather than, again, someone telling me what to do. And you get to interact with it,

P30: I'm gonna say I think she slowed me down a bit.
I think I would have been a bit quicker if I'd been working alone.

Fear of appearing stupid/Self-Doubt

P1: I think that's with everything I'm doing, every assignment, every homework, "it can't be that easy", so that was in my head, at the back, this little voice "it's definitely not just that", so I was trying to take it apart.

P5: if there was some else there, I'd literally be like [pulls serious face] and "they'll think I'm dumb"
So I think working alone was better, for me anyway, because I wouldn't have that awkwardness with someone where I'm quietly thinking away.
if there was someone else there, I think that I'd be kinda like if they had a solution, I'd forget about what I was thinking and go along with them, cos I'm kinda like "you're better than me, that's great, work away"
I'd be more like leaning towards them, "you're so right", that's just how I am. "No, we won't do what I'm thinking, yours is definitely way better!"
P7: The reason I might feel like I'm will do very badly is based on my own experience with these puzzles of try and fail, try and fail, try and fail.

P28: I liked it on my own, to figure that myself.

P31: I felt in control, but I also felt a bit overwhelmed at the start.
Afterwards, it's a sense of achievement because I done it, rather than me and someone else.

P16: He'll probably know way more and I'll probably just be standing here like an idiot not knowing what to do.
Sometimes I felt a bit, not afraid to speak up but that I wouldn't be heard, but overall it was positive. I actually felt better about it because, me personally, if I was to come in to do this alone, I would have been totally overthinking it before I even came in altogether, but knowing that somebody was there, I felt way more confident and felt that I have somebody to fall back on really if I mess up.
I would go and put myself forward and "stop being silly now, just say what you need to say, because everyone else is going to it" be a bit selfish in that way.

Theme 5. "It was like giving in": The Dilemma of Agency

<u>Choice is good/relaxing</u>
P1: I wish I hadn't opened them… it was just like "Maybe I'm wrong", cos I was doubting myself a bit. I definitely would have... one clue.
when I saw all of them together, I didn't want to just do one, and do it fully and move on, I wanted to get a grasp of the whole thing first, and I didn't want to waste time on one thing, and then...in my head I think of a lot of things at the same time, and that's how I work best, so it was nice that I could go and read all of the puzzles and then…
It made my thoughts at the back of my head to be able to move around. It was just easier for me. I think I would have got really frustrated if I had to stick with one and move on.
It was nice and I felt more, that I was more free to do it and I felt that I'm not under such pressure to finish one and then move on. Everything was really good, I didn't feel frustrated if I had to stick with one and finish it all the way through
I wasn't as frustrated as in sticking to one thing, I had the freedom to move around.

P1: it allows immense freedom, and if it allows immense freedom, then that relieves stress and allows the thinking process to proceed
Again, it made you feel in control. I'm all about control

P3: whereas if you move onto the next one, you can take your mind off it for a second, and think about something in a different way and it will trigger something about this one over here.
Because I think my initial reasoning was, I'll do one, finish this one, then move on to the next one, finish that one. That kind of way. But, that didn't really work [laughs]. So, that was frustrating.
I would've definitely spent 5 minutes with each, and then been like "whichever one is the easiest, get that one done."
I definitely had more freedom. I felt like the more I was going around and doing bits of all three of them, the more I was figuring out bits of the next one, if that makes sense?

P4: Actually no, I don't think so, cos then I know I would have tried with The Lift first, and if I hadn't gotten The Lift first, I would have given up.

P5: I started off here [referring to The Scarecrow] cos this was the first one to me, and I was like "No", cos you need to ease into those things, cos when you're given a big problem, you're like "argghhh!" I went for the less intimidating one, I was "No, I won't start with that". I got that one [The Lamp], and I knew that I'd struggled with this [Scarecrow], so I was ok, I'll do something different again, I won't go back to that.
I think it suited me to a tee, cos that's what I do anyway. I find if I'm given an assignment and it's 3 parts, I'm doing the 1st part and then I get an idea for the 3rd part and I'm like "skip down!" and I do this little bit, and put this over here, and then I have to go back. That's how I work anyway.
It suited me perfectly. I would have got totally frustrated if I wasn't allowed move on unless I got one done. I would have got too stuck down on it and probably would have went off in the wrong direction. I think the ability to roam around and see...

P6: I think because I knew I had the clues, I'll attempt it by myself for a minute and if I don't get it, I'll go to the clues immediately. They were kind of a backup.

P11: But I think that I had this freedom to move about the place. When I was on The Lamp, I was "ok, I'm running out of time!", that I could just leave it and go on to the next one.
I didn't have to solve that to go on to the next one.

P7: Feels good. If you've ever...it's never a pleasant feeling to be railroaded down one path, one solution. It feels like you're given a sense of power over the situation, in which you've been thrown into with no foresight.

P14: I can chance my arm with this, if it doesn't work, I'll just move on to something else, if that doesn't work, I'll move on to something else and then come back. In that sense, it took the...it took a little bit of the time pressure off so that I could move on to something without...without having to finish one thing. If I had to finish one thing, I might not have gotten any done, before I could move on…it just gives you a lot more

freedom in your thinking, and in...Probably aids your understanding a lot more as well.

P21: Being able to move between puzzles, because if I feel like I'm getting stuck in a puzzle, or I'm like whatever...just not entirely sure of it, if I'm stuck on the puzzle and I can't move anywhere, then I have to stay working on it before I can get onto the next one.
It's a challenge, it's a puzzle. It kind of defeats the purpose if you're taking out the answer as you're working on it.
and then in that case it's not a challenge, it's not even a puzzle. It's pretty much back to rote learning
P3: Having the choice to move on to the next one definitely maybe a little less...serious, if that makes sense? It kind of it made it a little bit more fun, more...I didn't feel pressured, yeah I didn't feel pressured that I had to get this one right to move onto the next one, so it was nice just to be able to walk around and do this I suppose…It did kind of make me a little bit less stressed about the whole thing.

P31: Being able to move around obviously affected the 1st one, because I was able to move on. Then, I thought "if I get the next one, I'll be a bit more clear-minded for this one"

P15: Yeah giving in. That's exactly it. Like I said, I'm stubborn.

P16: It opened up...I felt way more at ease because I knew I had that choice, and if we were to start at The Lamp one, for example, and not know that we could have moved on, maybe if we weren't told that and couldn't ask questions, we might have been at it longer and wasted time and not completed the other 2. Knowing that we could move on and we had a choice and it was free, it was really good. I think that impacted it really positively.
The fact that we did have a choice and it was open to us and we could do whatever…I really like that part of it because you just felt more at ease and when you're more at ease, you think clearer and can go ahead and fix things easier.

P24: I feel like was there was the aspect of failure there as well.
RESEARCHER: You definitely wanted to do them without the clues? P24: Yeah!

P26: No, I liked it. It was like a freedom element, you can do you want.

P27: There wouldn't be clues! Someone be like "Here. This is a good idea, you should probably do that!" You're on your own, you have to think by yourself. That's why I wanted to do...I knew the clues were an option and near the end, obviously, I just wanted to know what the answer was, so I just used to clues, but they brought in a different factor to it.

P30: I wanted to do them without the clues, but then we were running out of time on the elevator one...
RESEARCHER: Fair enough.
P30: Not the elevator, the other one [The Scarecrow]...it was frustrating the two of us. We just said "we'll go for a clue"

CLUES (linked with Determination to Solve)

P1: And accessing the clues, the cheats would only...
Least favourite would be the frustration aspect and knowing that, OK, if you don't get it, you can cheat, the option of cheating is not a good learning experience.

P3: I didn't want to open the clues, just cos I'm really stubborn, and...
It's kind of like cheating. I know it's not, but that's how I feel about it. It's like "Here's a clue!" I kind of felt like it was cheating a little bit. I know it's not, cos you're allowed to, but that's just how I felt about it, j'know?
P5: OK, my main goal was to solve all of them, so I'm gonna use these [clues] if it means I'm gonna solve it quicker. So that's why I jumped to the clues.

I was annoyed I used the clue cos I did know, I had a good idea of how to solve that.

P8: No, definitely not. The whole point of being able to do puzzles is you want to do it right, so if there's something to help you do it right, then why wouldn't you take it?

P7: The clues were, they were good. I almost don't like them, because they feel like giving up, they feel like, almost self-defeating, they give you a sense of defeatism because you feel like "I shouldn't need these!", but you do and therefore I'm a failure.

P13: I wish I'd just...if I was to do it again, I would have looked at each one, and would've went for one...if I was to go again, I would take the 1st clue from each one, and weigh up the options.

P14: Knowing that they were there meant that...you had a...almost like a couple of lives, like a couple of "get out of jail free" cards, but you...I suppose you didn't really know what clues were.
…the reason I didn't look at the clues immediately was that I wanted to challenge myself and see if I could get it without any assistance.
…for The Scarecrow, I absolutely dived into the clues because I was under time pressure.
The choice element added to the ...took away an awful lot of pressure, I think. I know I keep saying pressure even though there's no pressure involved in it, but...
I suppose pressure comes from the timing and internalized pressure, but...it took away some of the pressure, and it made the problems seem less serious.

P19: I think it was good, because it was "oh, I'm challenging myself!" and you might try more things, go more outside the box, and you see the clue and you're "oh!"...but it was really good to have them cos it could really direct you if you really got lost.

P20: That was good, because especially as there was a time limit on it, you had a choice of getting a bit of help. It took the pressure off, because pressure isn't great to work under either.

P3: Looking at the clues, or having to look at the clues, I felt a little bit defeated. "Oh I can't figure this out, I have to look at it!"
You don't have to do everything by yourself, so was kind of nice to have that option. And then...but the fact that it was an option and I didn't have to use it for the last one

kinda made me feel a little bit better that I was actually able to figure it out by myself as well, without having to use the clues.

P28: I was really annoyed...I didn't want to look at the clues. So, I think that wasted me a lot of time
No I didn't mind doing it by myself. I liked figuring it out, but it's just the fact that I didn't want to look at the clues. I kind of got over that by the 2nd round, skipped the 2nd one, and got over by the 3rd one because I realised how little time I had. But definitely...I don't know...proving to myself that I could do it without the clues even though there was no...penalty or anything for using them. I just didn't want to. I don't know why.

P28: I always just try to do it without any prompting. I don't know why. I just do.

P31: I was reluctant to take the clues at the start, because I would rather figure it out myself, but I think the choice of having them there and the temptation when I was getting anywhere frustrated, I thought "I might just taking a clue and it might help!"

P31: I thought the freedom of being able to choose which one you went to, and not having to finish one make made me felt a little more relieved and less pressured, cause I think I stuck with the 1st one for too long, and I couldn't move on until I finished it, I would've felt really pressured, and probably then thought "oh, if I'm bad at this one, I'll gonna be bad at the next two as well"

P9: I was thinking "let's do our best and let's try to solve it without peeking"

P16: Yeah, which I'm very proud of! And also, the fact that the ones we did use, we only did really want to do use 1. If we had to use 1 per puzzle, but the ones that we did use were the ones that we needed, they were exactly what we needed to know, so that was really good.

P11: I didn't want to access them!

P3: Yeah, a little bit. I felt like I didn't want to be left behind or I didn't want to be not contributing as much as my partner.
P3: I can see how other people, because I can tell...I know P24 very well, I could tell he didn't want to use any of the clues at all, because it seems like...like you're admitting that you need help.

Less Choice/More Guidance

P8: I went straight for what I thought was hardest. I was probably wrong with that…

P13: Yeah. I reckon even if there was a direction to take around the table? I think maybe, because it was given freedom of picking whichever one I want, maybe that put even more pressure on me.

P14: I think my thinking was "get the hard one done first"

P10: I felt it was a different thing for me, because if you told me “you go for this 1st, and that 2nd and then this” I would have...it would be streamlined and I would have divided it in an equal order. And I would have given this much time for this, this much time for this.

P11: I would have preferred less choice, but longer time. But that's only because I don't like to take the easy route, myself.

P17: I suppose it gave me the freedom of being like “ok, we’ll start with this one, and if we don't think this one’s easy, we might move on to other ones. I always want to get the easy ones out of the way so we’ll have the last thing, the hardest one left to the last so we can have the most time at that. But, you can’t tell which one is going to be easier or not.
P17: I got to move around between the different ones and then the pieces that I used to fix one were subtracted from the pile of pieces left to use for the other ones. Which was useful because if the pieces were gone, there are probably...the ones left over were for the other ones, so it gives you less of an amount to...figure out from.

P29: You have the freedom to pick what you like. But, at the same time, there’s just too many options, where do you start? What do you choose?

P29: 3 puzzles, even if it meant giving in. They just didn’t want to give in but misjudged the timing and looked at the clues too late to then formulate a solution and realise it.

Final Steps

A brief summary was made, and then each theme was reduced to a list of points, in an order that would lend itself to a coherent narrative.

Summary

Students across all levels enjoyed it. They were personally invested in solving the puzzles. They cared about the learning experience too, prideful and unwilling to use the clues, unless they had to.
They were happy when solving puzzles and oddly accepting of any reasonable failures. Not using the clues early enough was a common complaint.
They were bitter about tactical failures of judgement, or feelings that they “really should have got that”. When mistakes, (especially “fixation mistakes”), were made, participants were angry and bitter on reflection.
Self-Doubt was eased by the incremental nature of the puzzle-solving process.
Self-Doubt was “imagined” as being a major factor when working in a partnership, as the puzzles’ physical nature meant every “stupid suggestion” of theirs would be visible for judgement. All “relatedness” comments were always related to a partner improving their chances of solving the puzzles, with no real interest in emotional support.

Theme 1: "you could just try it, and then prove it in a second that it's wrong": The Physical Feedback Loop

Intellectual (not Emotional) Response to Physicality
Constructionism/ET-Cognitive: Ease of Visualisation/ Immediate Feedback/ Love of Puzzles/ How the physicality urged them towards active participation
ET-Cognitive = (use of strategic learning strategies, active self-regulation)

1	It was easier to simply look at it, instead of trying to visualise the problem.
2	It was easier to simply change it, instead of trying to imagine/visualise changes
3	Participants had arrived with/because of a Love of Puzzles
4	Cognitive Strategies: Start easy, avoidance of clues
5	Tangibility/Interaction in general
6	Physical feedback was cognitive: it helped them decide on their next step
7	Not just by 'seeing', but the pieces 'in hand' helped them think in a different way
	Any final points about 'determination to solve' flow into Theme 2

Theme 2. "I wanted…to see them complete and know that I'd done them fully":

Determined to solve, one step at a time
Emotional Response to Physicality
SDL-Competence/ET-Behavioural: Determination to Solve/ Determination to Learn/ Pride/ Reward/ Challenge/ Learned about Themselves/ Complaints about Existing Teaching Environments
ET-Emotional: Self-Doubt/2nd Guessing/Visually Overwhelmed
SDT-Competence (understanding how to attain various external and internal outcomes and being efficacious in performing the requisite actions)
ET-Behavioural (on-task attention, effort, persistence, lack of conduct problems)
ET-Emotional (presence of enthusiasm, absence of anger, anxiety, & boredom)

This maps the participants' articulation of how the physical nature of the puzzles related to being determined to solve; determined to learn; pride; how they learned about themselves, their self-doubt and repeated unprovoked criticism of existing teaching methods.

1	Determined to Solve: Not an intrinsic desire to learn, per se. Puzzles!!!
2	A sense of Reward
3	General sense of Pride/Challenge
5	Physicality encouraged/impelled participation
6	Challenge, Pride, Fun, all related to the physicality of the puzzles
7	Determined to learn from the experience
8	Learned something about themselves
9	Self-Doubt: Step-by-step nature of puzzle-solving eased this problem
	Criticism of other Teaching Methods shows they do take it all very seriously
10	No passion:
11	No clarity:
12	Didn't learn anything:
13	No emotional support:

Theme 3. "It's been giving me nightmares": The Bitterness of Failure
SDL-Competence/ET-Behavioural: Determination to Solve
ET-Emotional: Bitterness
SDT-Competence (understanding how to attain various external and internal outcomes and being efficacious in performing the requisite actions)
ET-Behavioural (on-task attention, effort, persistence, lack of conduct problems)
ET-Emotional (presence of enthusiasm, absence of anger, anxiety, & boredom)
This maps the participants' emotional reaction to their individual performance and highlights the marked difference in the intensity of their reactions between success and failure.

1	Fun/Happy/Excited
2	Engaged
3	Disappointment
4	Regret
5	Time Pressure
6	Bitterness/Fixation

Theme 4. "I think she slowed me down": Sharing is one thing, winning is everything
SDL-Relatedness/ET-Behavioural: Determination to Solve
ET-Cognitive; ET-Emotional
SDT-Relatedness (developing secure and satisfying connections with others)
ET-Cognitive (use of strategic learning strategies, active self-regulation)
This theme demonstrates that relatedness/fellowship between participants, while not unappreciated, was only important when directly providing help solving the puzzles, rather than a sharing of the experience.

1	Determination to do well, so comments were always related to that…
2	Cognitive Support
3	Emotional Support
4	Prefer to be alone
5	Hindered by companion!
6	Mention of Self-Doubt
7	Fear of appearing stupid
8	Comments not related to Efficiency
9	Caring and Sharing

Theme 5. "It was like giving in": The Dilemma of Agency

SDT-Autonomy: Freedom to move from 1 puzzle to another at will.
ET-Agentic: Related to the clues/help
SDT-Autonomy (being self-initiating and self-regulating of one's own actions)
ET-Agentic (students' contribution into the flow of the instruction they receive)
This theme explores how participants felt that the freedom of choice was reassuring, that the freedom to move between puzzles without having to complete one to "qualify" for the next round reduced their stress levels. Related to the previous Theme, where companionship/freedom was fine, but only when it helped solve the puzzles.

1	Choice is good (freedom of movement)
2	Choice is good (clues)
3	Choice is relaxing
5	Choice = less guidance
4	Accessing clues was giving in; Pride came into play
6	Solving was a priority